DIODES INCORPORATED

1N4001 - 1N4007

1.0A RECTIFIER

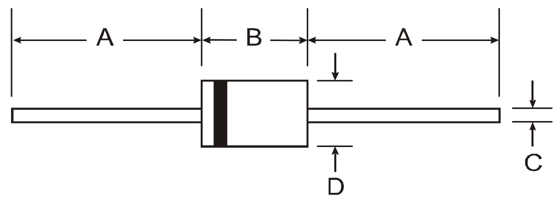
Please click here to visit our online spice models database.

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- **Lead Free Finish, RoHS Compliant (Note 3)**

Mechanical Data

- Case: DO-41
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Mounting Position: Any
- Ordering Information: See Page 2
- Marking: Type Number
- Weight: 0.30 grams (approximate)



Dim	DO-41 Plastic	
	Min	Max
A	25.40	—
B	4.06	5.21
C	0.71	0.864
D	2.00	2.72
All Dimensions in mm		

Maximum Ratings and Electrical Characteristics @T_A = 25°C unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ T_A = 75°C	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load	I_{FSM}	30							A
Forward Voltage @ I_F = 1.0A	V_{FM}	1.0							V
Peak Reverse Current @T_A = 25°C at Rated DC Blocking Voltage @ T_A = 100°C	I_{RM}	5.0 50							μA
Typical Junction Capacitance (Note 2)	C_j	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	T_A	+150							°C
Operating and Storage Temperature Range	T_J, T_{STG}	-65 to +150							°C

Notes:
1. Leads maintained at ambient temperature at a distance of 9.5mm from the case.
2. Measured at 1.0 MHz and applied reverse voltage of 4.0V DC.
3. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied, see EU Directive 2002/95/EC Annex Notes.

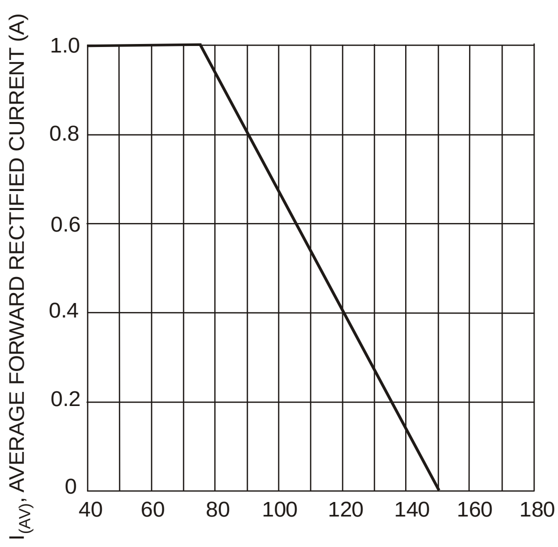


Fig. 1 Forward Current Derating Curve

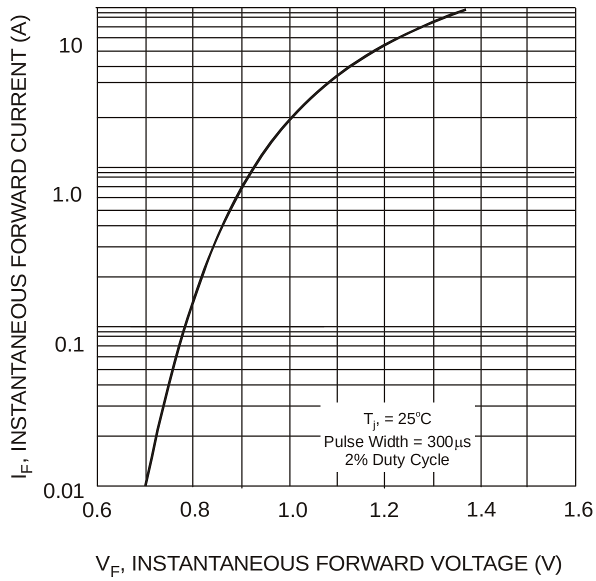


Fig. 2 Typical Forward Characteristics

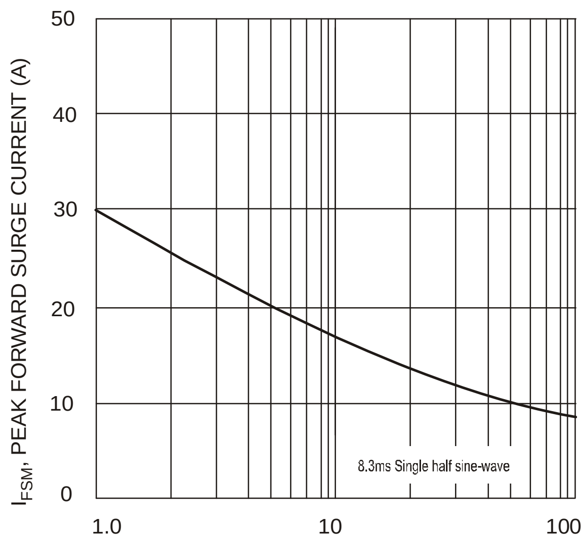


Fig. 3 Max Non-Repetitive Peak Fwd Surge Current

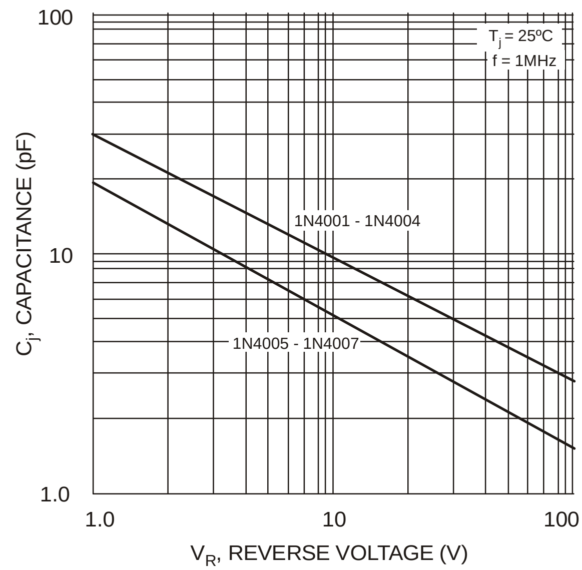


Fig. 4 Typical Junction Capacitance

Ordering Information (Note 4)

Device	Packaging	Shipping
1N4001-B	DO-41 Plastic	1K/Bulk
1N4001-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4002-B	DO-41 Plastic	1K/Bulk
1N4002-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4003-B	DO-41 Plastic	1K/Bulk
1N4003-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4004-B	DO-41 Plastic	1K/Bulk
1N4004-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4005-B	DO-41 Plastic	1K/Bulk
1N4005-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4006-B	DO-41 Plastic	1K/Bulk
1N4006-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4007-B	DO-41 Plastic	1K/Bulk
1N4007-T	DO-41 Plastic	5K/Tape & Reel, 13-inch

Notes: 4. For packaging details, visit our website at http://www.diodes.com/datasheets/ap02008.pdf.

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National Semiconductor

June 1989

5409/DM7409 Quad 2-Input AND Gates with Open-Collector Outputs

General Description

This device contains four independent gates each of which performs the logic AND function. The open-collector outputs require external pull-up resistors for proper logical operation.

Pull-Up Resistor Equations

$$R_{MAX} = \frac{V_{CC}\,(\text{Min}) - V_{OH}}{N_1\,(I_{OH}) + N_2\,(I_{IH})}$$

$$R_{MIN} = \frac{V_{CC}\,(\text{Max}) - V_{OL}}{I_{OL} - N_3\,(I_{IL})}$$

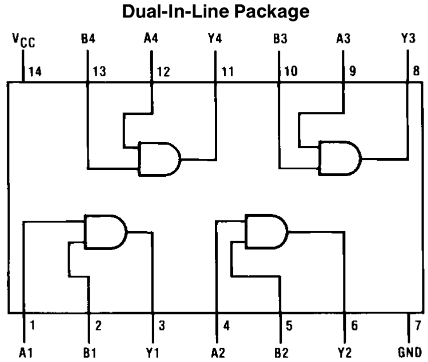
Where: N_1 (I_{OH}) = total maximum output high current for all outputs tied to pull-up resistor

N_2 (I_{IH}) = total maximum input high current for all inputs tied to pull-up resistor

N_3 (I_{IL}) = total maximum input low current for all inputs tied to pull-up resistor

Connection Diagram

Dual-In-Line Package



TL/F/6499–1

Order Number 5409DMQB, 5409FMQB or DM7409N
See NS Package Number J14A, N14A or W14B

Function Table

Y = AB

Inputs		Output
A	**B**	**Y**
L	L	L
L	H	L
H	L	L
H	H	H

H = High Logic Level
L = Low Logic Level

 TL/F/6499

RRD-B30M105/Printed in U. S. A.

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	7V
Input Voltage	5.5V
Output Voltage	7V
Operating Free Air Temperature Range	
54	−55°C to +125°C
DM74	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note: *The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.*

Recommended Operating Conditions

Symbol	Parameter	5409			DM7409			Units
		Min	Nom	Max	Min	Nom	Max	
V_{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High Level Input Voltage	2			2			V
V_{IL}	Low Level Input Voltage			0.8			0.8	V
V_{OH}	High Level Output Voltage			5.5			5.5	V
I_{OL}	Low Level Output Current			16			16	mA
T_A	Free Air Operating Temperature	−55		125	0		70	°C

Electrical Characteristics over recommended operating free air temperature range (unless otherwise noted)

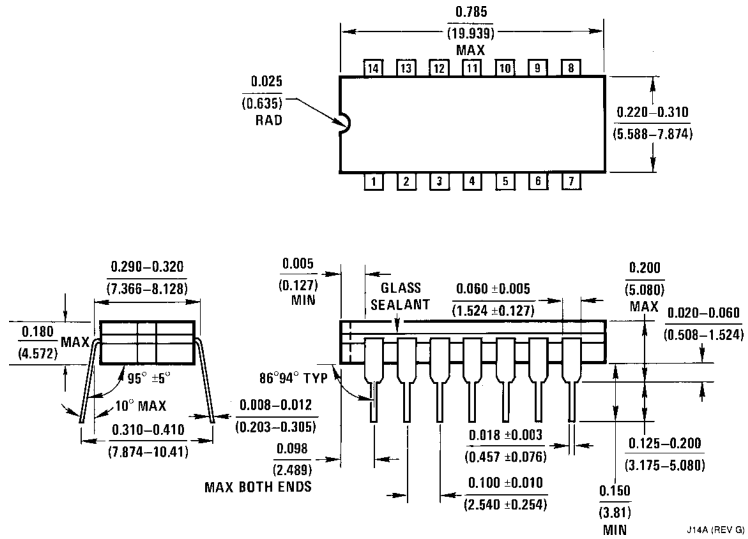
Symbol	Parameter	Conditions	Min	Typ (Note 1)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −12 mA			−1.5	V
I_{CEX}	High Level Output Current	V_{CC} = Min, V_O = 5.5V V_{IH} = Min			250	μA
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max V_{IL} = Max		0.2	0.4	V
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 5.5V			1	mA
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.4V			40	μA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V			−1.6	mA
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max		11	21	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max		20	33	mA

Switching Characteristics at V_{CC} = 5V and T_A = 25°C (See Section 1 for Test Waveforms and Output Load)

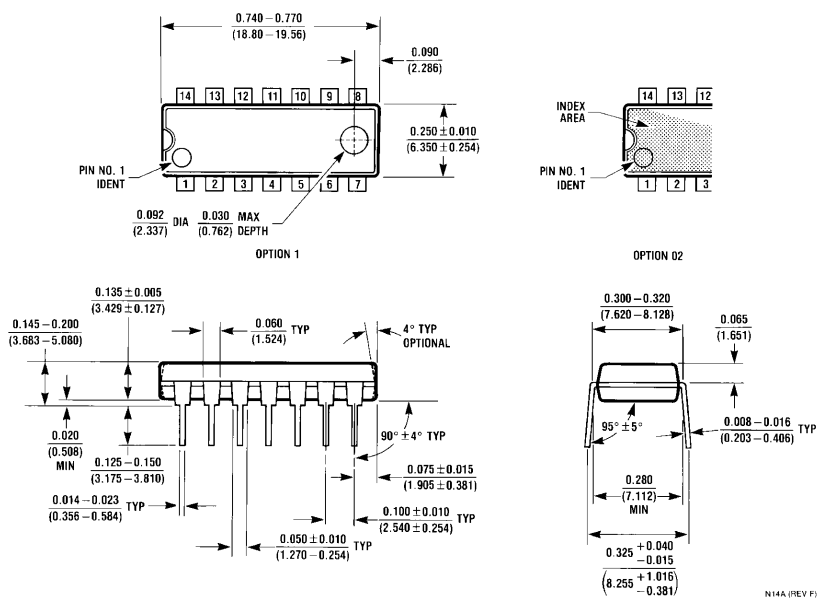
Symbol	Parameter	Conditions	Min	Max	Units
t_{PLH}	Propagation Delay Time Low to High Level Output	C_L = 15 pF R_L = 400Ω		32	ns
t_{PHL}	Propagation Delay Time High to Low Level Output			24	ns

Note 1: All typicals are at V_{CC} = 5V, T_A = 25°C.

Physical Dimensions inches (millimeters)

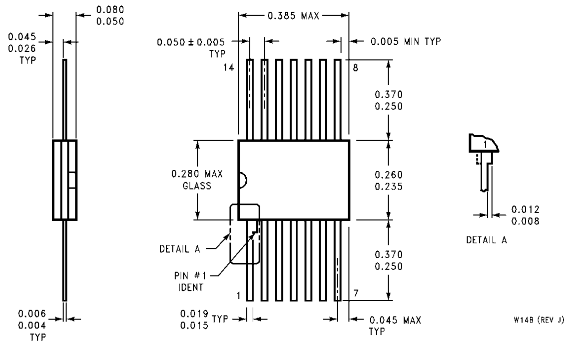


14-Lead Ceramic Dual-In-Line Package (J)
Order Number 5409DMQB
NS Package Number J14A



14-Lead Molded Dual-In-Line Package (N)
Order Number DM7409N
NS Package Number N14A

Physical Dimensions inches (millimeters) (Continued)



14-Lead Ceramic Flat Package (W)
Order Number 5409FMQB
NS Package Number W14B

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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BC 337 · BC 338

NPN SILICON AF MEDIUM POWER TRANSISTORS

THE BC337, BC338 ARE NPN SILICON PLANAR EPITAXIAL TRANSISTORS FOR USE IN AF DRIVER AND OUTPUT STAGES, AS WELL AS FOR UNIVERSAL APPLICATIONS. THE BC337, BC338 ARE COMPLEMENTARY TO THE PNP TYPE BC327, BC328 RESPECTIVELY.

CASE TO-92F

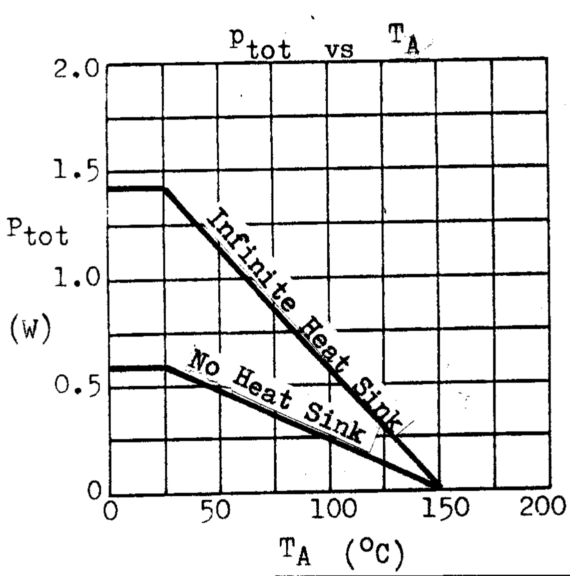
CEB

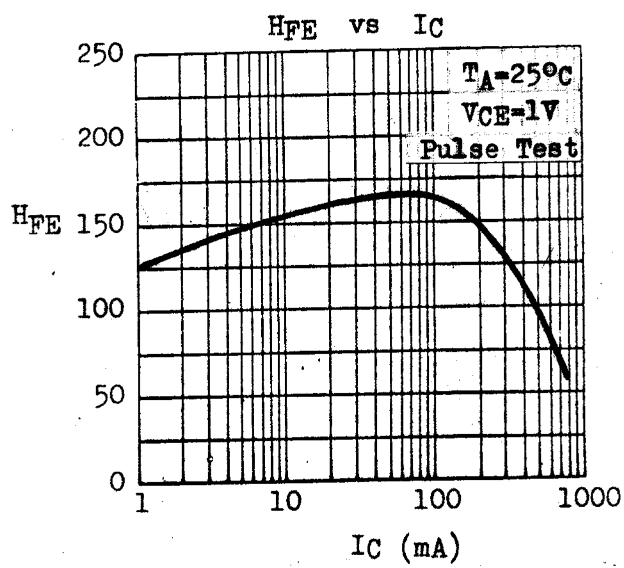
ABSOLUTE MAXIMUM RATINGS

		BC337	BC338
Collector-Emitter Voltage ($V_{BE}=0$)	V_{CES}	50V	30V
Collector-Emitter Voltage ($I_B=0$)	V_{CEO}	45V	25V
Emitter-Base Voltage	V_{EBO}	5V	
Collector Current	I_C	0.8A	
Collector Peak Current ($t \leq 10mS$)	I_{CM}	1.5A	
Total Power Dissipation (@ $T_C \leq 25°C$)	P_{tot}	1.4W	
(@ $T_A \leq 25°C$)		625mW	
Operating Junction & Storage Temperature	T_j, T_{stg}	-55 to 150°C	

THERMAL RESISTANCE

Junction to Case	θ_{jc}	90°C/W	max.
Junction to Ambient	θ_{ja}	200°C/W	max.





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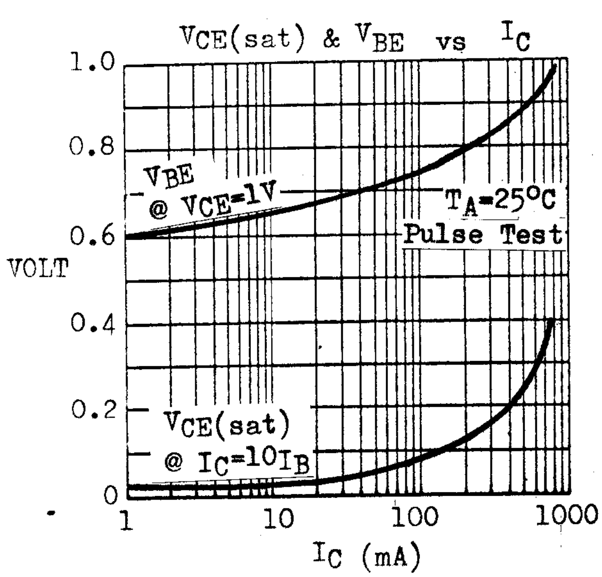
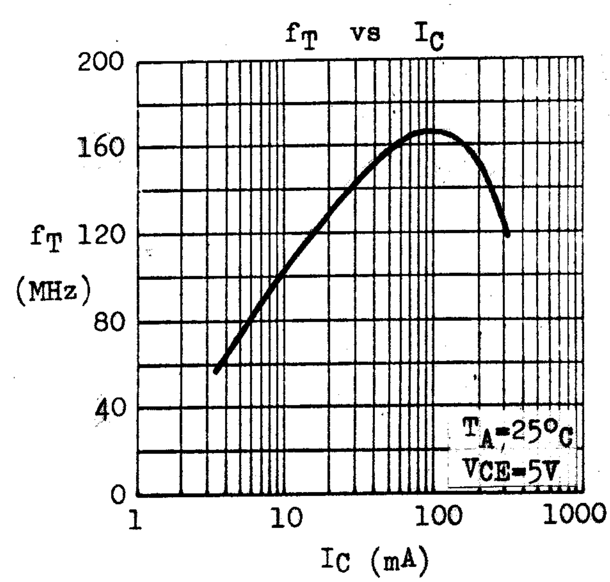
KWUN TONG P. O. BOX69477 CABLE ADDRESS "MICROTRON"
TELEPHONE:- 3-430181-6
FAX: 3-410321

ELECTRICAL CHARACTERISTICS (T_A=25°C unless otherwise noted)

PARAMETER	SYMBOL	BC337 MIN	BC337 TYP	BC337 MAX	BC338 MIN	BC338 TYP	BC338 MAX	UNIT	TEST CONDITIONS
Collector-Emitter Breakdown Voltage	BV_{CES}	50			30			V	I_C=0.1mA V_{BE}=0
Collector-Emitter Breakdown Voltage	LV_{CEO} *	45			25			V	I_C=10mA I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	5			5			V	I_E=0.1mA I_C=0
Collector Cutoff Current	I_{CES}			100				nA	V_{CES}=45V
							100	nA	V_{CES}=25V
				10				µA	V_{CES}=45V T_A=125°C
							10	µA	V_{CES}=25V T_A=125°C
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$*			0.7			0.7	V	I_C=500mA I_B=50mA
Base-Emitter Voltage	V_{BE} *			1.2			1.2	V	I_C=300mA V_{CE}=1V
D.C. Current Gain	H_{FE} *	100		630	100		630		I_C=100mA V_{CE}=1V
Group 16 (A)		100		250	100		250		
Group 25 (B)		160		400	160		400		
Group 40 (C)		250		630	250		630		
All Groups		40			40				I_C=300mA V_{CE}=1V
H_{FE} Matched Pair Ratio	$\frac{H_{FE}\,1}{H_{FE}\,2}$ *			1.41			1.41		I_C=100mA V_{CE}=1V
Current Gain-Bandwidth Product	f_T		100			100		MHz	I_C=10mA V_{CE}=5V
Collector-Base Capacitance	Cob		10			10		pF	V_{CB}=10V I_E=0 f=1MHz

* Pulse Test : Pulse Width=0.3mS, Duty Cycle=1%





2,8 VA encapsulated transformers (T40/E)

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Part nr.	Power (VA)	Core type	Primary Voltage	Secondary Voltage	Secondary Intensity	Remark	Approval
406928	2,8	EI 30/18		6V	0,47A	*Short circuit proof*	1 - 2
407928	2,8	EI 30/18		7,5V	0,37A	*Short circuit proof*	1 - 2
409928	2,8	EI 30/18		9V	0,31A	*Short circuit proof*	1 - 2
412928	2,8	EI 30/18	**230V**	12V	0,23A	*Short circuit proof*	1 - 2
415928	2,8	EI 30/18		15V	0,19A	*Short circuit proof*	1 - 2
418928	2,8	EI 30/18		18V	0,16A	*Short circuit proof*	1 - 2
424928	2,8	EI 30/18		24V	0,12A	*Short circuit proof*	1 - 2

Part nr.	Power (VA)	Core type	Primary Voltage	Secondary Voltage	Secondary Intensity	Remark	Approval
506928	2,8	EI 30/18		6+6V	0,23A	*Short circuit proof*	1
507928	2,8	EI 30/18		7,5V+7,5V	0,19A	*Short circuit proof*	1
509928	2,8	EI 30/18		9+9V	0,16A	*Short circuit proof*	1
512928	2,8	EI 30/18	**230V**	12+12V	0,12A	*Short circuit proof*	1
515928	2,8	EI 30/18		15+15V	0,10A	*Short circuit proof*	1
518928	2,8	EI 30/18		18+18V	0,08A	*Short circuit proof*	1
524928	2,8	EI 30/18		24+24V	0,06A	*Short circuit proof*	1

Part nr.	Power (VA)	Core type	Primary Voltage	Secondary Voltage	Secondary Intensity	Remark	Approval

Single Digit LED Numeric Display

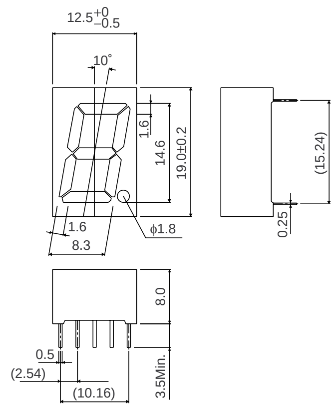
LA-601 B / L Series

LA-601 B / L series is designed to use in the light. Materials of emission are GaAsP on GaP, AlGaInP GaP and GaN. This is the height of a letter 14.6mm, single digit LED Numeric Display that is packed by epoxy resin.

●Features

1) The height of a letter is 14.6mm.
2) Dimension is 12.5×19.0×8.0mm.
3) The package of surface color is black. Color of segment is colored in emitting color. (Blue color is only milky white)
4) Each color has anode common and cathode common respectively.

●Dimensions (Unit : mm)

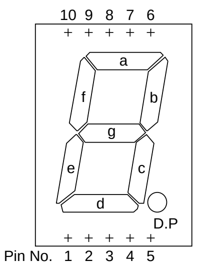


Tolerance are ±0.3 unless otherwise noted:

●Selection guide

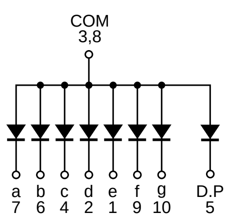
Emitting color / Common	Red	Red (High brightness)	Orange (High brightness)	Yellow (High brightness)	Green	Blue
Anode	LA-601VB	LA-601AB	LA-601EB	LA-601XB	LA-601MB	LA-601BB
Cathode	LA-601VL	LA-601AL	LA-601EL	LA-601XL	LA-601ML	LA-601BL

●Pin assignments

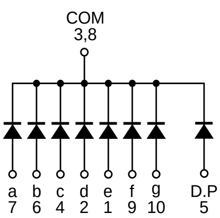


Pin No.	Function
1	Segment "e"
2	Segment "d"
3	Common
4	Segment "c"
5	D.P
6	Segment "b"
7	Segment "a"
8	Common
9	Segment "f"
10	Segment "g"

●Equivalent circuit (anode common)



(cathode common)



●Absolute maximum ratings (Ta=25°C)

Parameter	Symbol	Red	Red (High brightness)	Orange (High brightness)	Yellow (High brightness)	Green	Blue	Unit
		LA-601VB / VL	LA-601AB / AL	LA-601EB / EL	LA-601XB / XL	LA-601MB / ML	LA-601BB / BL	
Power dissipation	P_D	480	520	520	520	480	336	mW
Power dissipation	P_D / seg	60	65	65	65	60	42	mW
Forward current	I_F	20	25	25	25	20	10	mA
Peak forward current	I_{FP}	60 *1	50 *2	50 *2	50 *2	60 *1	50 *2	mA
Reverse voltage	V_R	5	5	5	5	5	5	V
Operating temperature	Topr	−25 to +75						˚C
Storage temperature	Tstg	−30 to +85						˚C

*1 Pulse width 1ms Duty 1 / 5
*2 Pulse width 0.1ms Duty 1 / 10

●Electrical characteristics (Ta=25°C)

Parameter	Symbol	Conditions	Red		Red (High brightness)		Orange (High brightness)		Yellow (High brightness)		Green		Blue		Unit
			Typ.	Max.	Typ.	Max.	Typ.	Max.	Typ.	Max.	Typ.	Max.	Typ.	Max.	
Forward voltage	V_F	I_F=10mA	2.0	2.8	2.05*	2.6*	2.05*	2.6*	2.05*	2.6*	2.1	2.8	3.6	4.2	V
Reverse current	I_R	V_R=3V	–	100	–	100	–	100	–	100	–	100	–	100	μA
Peak wavelength	λ_P	I_F=10mA	650	–	626*	–	610*	–	589*	–	563	–	470	–	nm
Spectral line half width	$\Delta\lambda$	I_F=10mA	40	–	18*	–	17*	–	15*	–	40	–	26	–	nm

◎The products are not radiations resistant.
* Shows the number on the condition of I_F=20mA.

●Luminous intensity

Color	λ_P (nm)	Type	Min.	Typ.	Unit
Red	650	LA-601VB	5.6	14	mcd
		LA-601VL			
Red (High brightness)	626	LA-601AB	36	90	mcd
		LA-601AL			
Orange (High brightness)	610	LA-601EB	36	90	mcd
		LA-601EL			
Yellow (High brightness)	589	LA-601XB	36	90	mcd
		LA-601XL			
Green	563	LA-601MB	9	22	mcd
		LA-601ML			
Blue	470	LA-601BB	14	56	mcd
		LA-601BL			

◎A condition of measurement is I_F=10mA.

●Electrical and optical characteristic curves

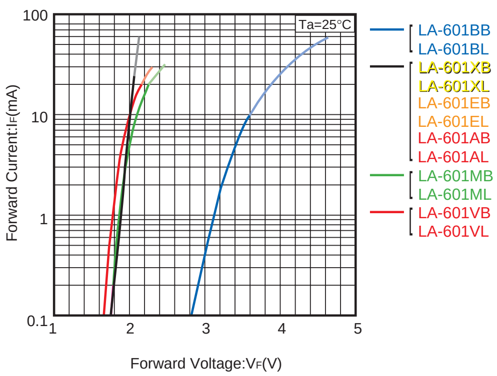


Fig.1 Forward Current - Forward Voltage

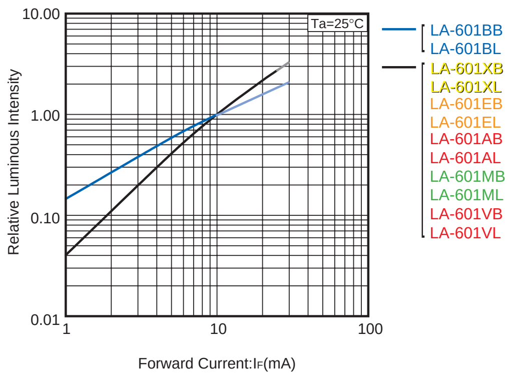


Fig.2 Relative Luminous Intensity - Forward Current

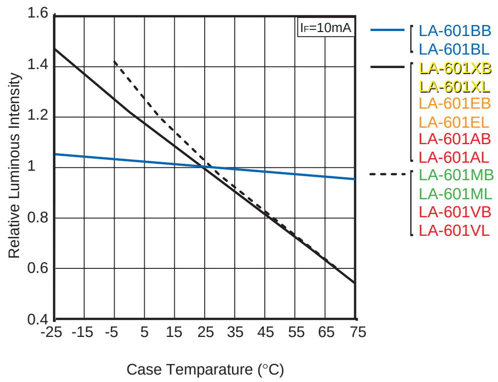


Fig.3 Relative Luminous Intensity - Case Temperature

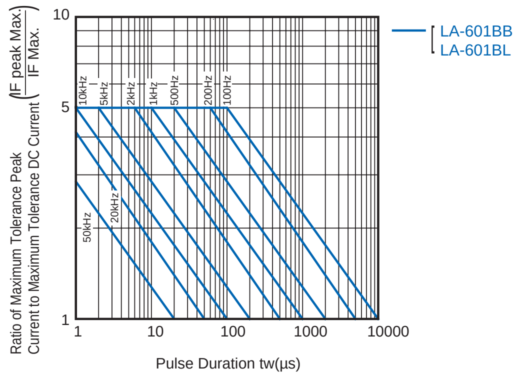


Fig.4 Ratio of Maximum Tolerable Peak Current - Pulse Duration (I)

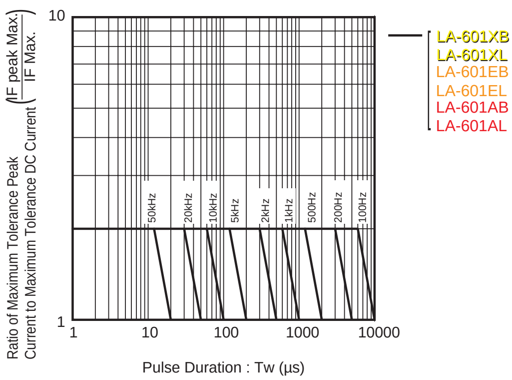


Fig.5 Ratio of Maximum Tolerable Peak Current - Pulse Duration (II)

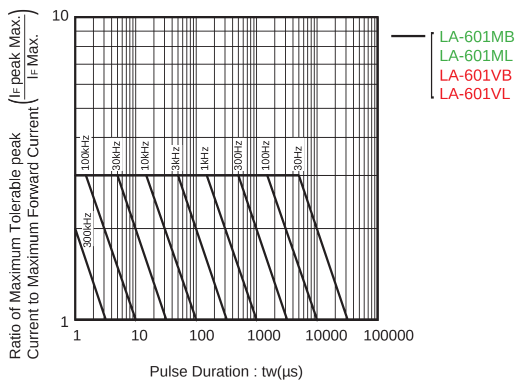


Fig.6 Ratio of Maximum Tolerable Peak Current - Pulse Duration (III)

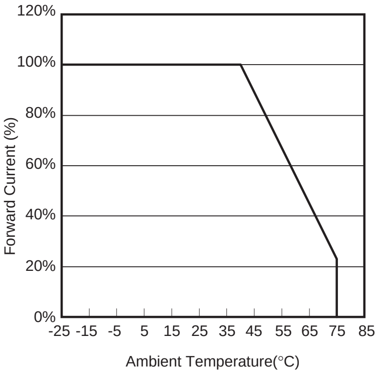


Fig.7 Derating

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DATA SHEET

For a complete data sheet, please also download:

- The IC04 LOCMOS HE4000B Logic Family Specifications HEF, HEC
- The IC04 LOCMOS HE4000B Logic Package Outlines/Information HEF, HEC

HEF4511B
MSI
BCD to 7-segment latch/decoder/driver

Product specification
File under Integrated Circuits, IC04

January 1995

BCD to 7-segment latch/decoder/driver

DESCRIPTION

The HEF4511B is a BCD to 7-segment latch/decoder/driver with four address inputs (D_A to D_D), an active LOW latch enable input ($\overline{EL}$), an active LOW ripple blanking input ($\overline{BI}$), an active LOW lamp test input ($\overline{LT}$), and seven active HIGH n-p-n bipolar transistor segment outputs (O_a to O_g).

When $\overline{EL}$ is LOW, the state of the segment outputs (O_a to O_g) is determined by the data on D_A to D_D.
When $\overline{EL}$ goes HIGH, the last data present on D_A to D_D are stored in the latches and the segment outputs remain stable. When $\overline{LT}$ is LOW, all the segment outputs are HIGH independent of all other input conditions. With $\overline{LT}$ HIGH, a LOW on $\overline{BI}$ forces all segment outputs LOW. The inputs $\overline{LT}$ and $\overline{BI}$ do not affect the latch circuit.

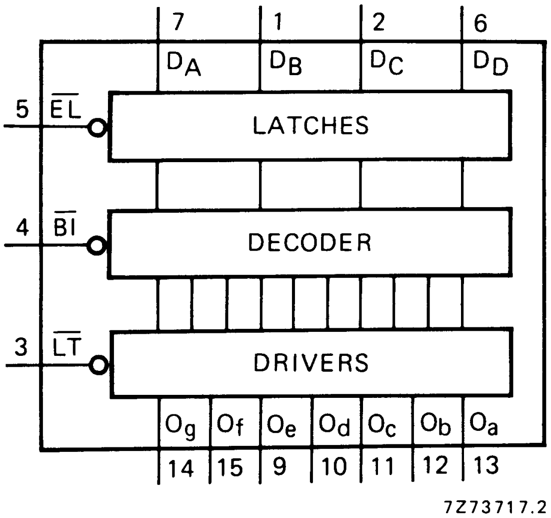


Fig.1 Functional diagram.

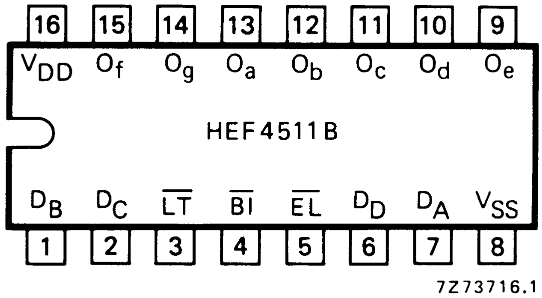


Fig.2 Pinning diagram.

HEF4511BP(N):	16-lead DIL; plastic (SOT38-1)
HEF4511BD(F):	16-lead DIL; ceramic (cerdip) (SOT74)
HEF4511BT(D):	16-lead SO; plastic (SOT109-1)

( ): Package Designator North America

PINNING

D_A to D_D	address (data) inputs
$\overline{EL}$	latch enable input (active LOW)
$\overline{BI}$	ripple blanking input (active LOW)
$\overline{LT}$	lamp test input (active LOW)
O_a to O_g	segment outputs

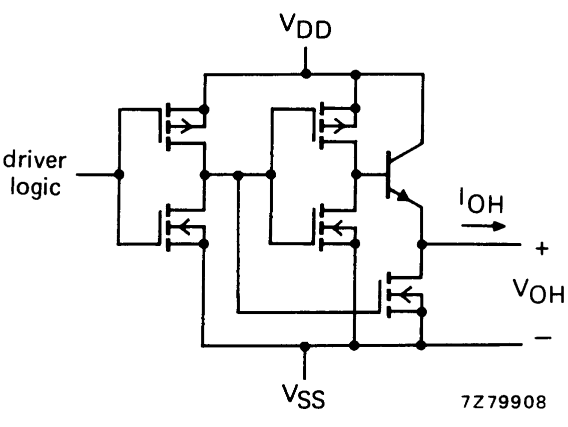


Fig.3 Schematic diagram of output stage.

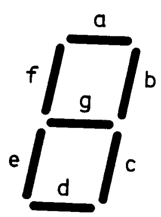


Fig.4 Segment designation.

FAMILY DATA, I_{DD} LIMITS category MSI

See Family Specifications

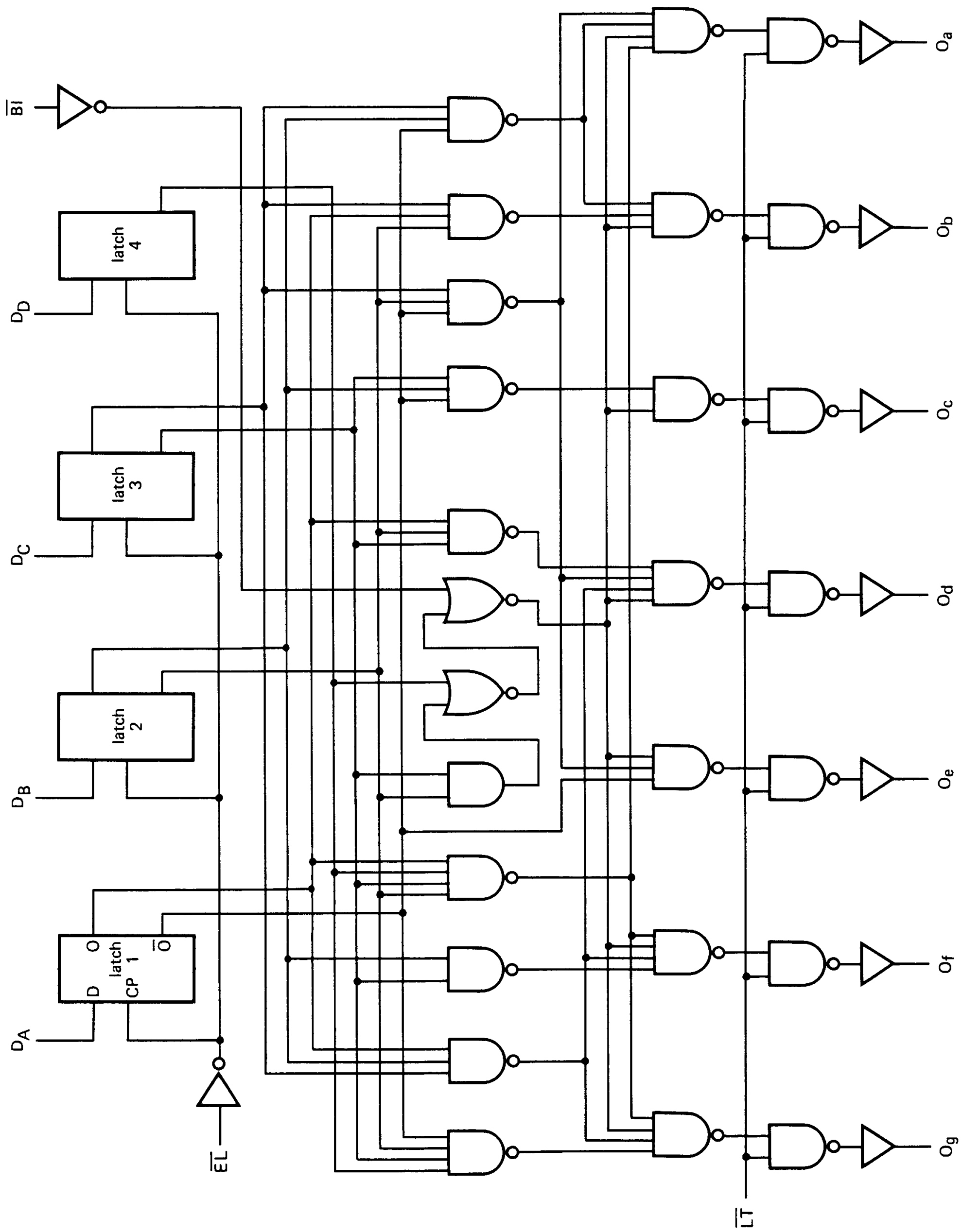


Fig.5 Logic diagram; for one latch see Fig.6.

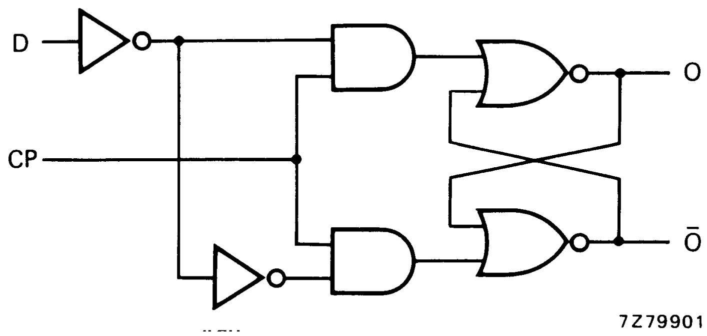


Fig.6 Logic diagram (one latch); see also Fig.5.

FUNCTION TABLE

INPUTS							OUTPUTS							
$\overline{EL}$	$\overline{BI}$	$\overline{LT}$	D_D	D_C	D_B	D_A	O_a	O_b	O_c	O_d	O_e	O_f	O_g	DISPLAY
X	X	L	X	X	X	X	H	H	H	H	H	H	H	8
X	L	H	X	X	X	X	L	L	L	L	L	L	L	blank
L	H	H	L	L	L	L	H	H	H	H	H	H	L	0
L	H	H	L	L	L	H	L	H	H	L	L	L	L	1
L	H	H	L	L	H	L	H	H	L	H	H	L	H	2
L	H	H	L	L	H	H	H	H	H	H	L	L	H	3
L	H	H	L	H	L	L	L	H	H	L	L	H	H	4
L	H	H	L	H	L	H	H	L	H	H	L	H	H	5
L	H	H	L	H	H	L	L	L	H	H	H	H	H	6
L	H	H	L	H	H	H	H	H	H	L	L	L	L	7
L	H	H	H	L	L	L	H	H	H	H	H	H	H	8
L	H	H	H	L	L	H	H	H	H	L	L	H	H	9
L	H	H	H	L	H	L	L	L	L	L	L	L	L	blank
L	H	H	H	L	H	H	L	L	L	L	L	L	L	blank
L	H	H	H	H	L	L	L	L	L	L	L	L	L	blank
L	H	H	H	H	L	H	L	L	L	L	L	L	L	blank
L	H	H	H	H	H	L	L	L	L	L	L	L	L	blank
L	H	H	H	H	H	H	L	L	L	L	L	L	L	blank
H	H	H	X	X	X	X				*				*

Note

1. H = HIGH state (the more positive voltage)
   L = LOW state (the less positive voltage)
   X = state is immaterial
   * Depends upon the BCD code applied during the LOW to HIGH transition of $\overline{EL}$.

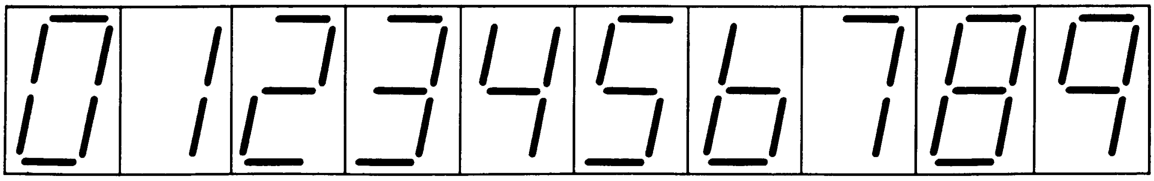


Fig.7 Display.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134).

Output (source) current HIGH	$-I_{OH}$	max.	25	mA

For other RATINGS see Family Specifications.

Note

1. A destructive high current mode may occur if V_I and V_O are not constrained to the range $V_{SS} \leq V_I$ or $V_O \leq V_{DD}$.

DC CHARACTERISTICS

V_{SS} = 0 V

HEF	V_{DD} V	I_{OH} mA	SYMBOL	T_{amb} (°C) −40 MIN.	MAX.	+ 25 MIN.	TYP.	+ 85 MIN.	MAX.	
Output voltage HIGH	5	0	V_{OH}	4,10		4,10	4,40	4,10		V
	10	0		9,10		9,10	9,40	9,10		V
	15	0		14,10		14,10	14,40	14,10		V
Output voltage HIGH	5	5	V_{OH}				4,20			V
	10	5					9,20			V
	15	5					14,20			V
Output voltage HIGH	5	10	V_{OH}	3,60		3,60	4,05	3,30		V
	10	10		8,75		8,75	9,10	8,45		V
	15	10		13,75		13,75	14,10	13,45		V
Output voltage HIGH	5	15	V_{OH}				4,00			V
	10	15					9,00			V
	15	15					14,00			V
Output voltage HIGH	5	20	V_{OH}	2,80		2,80	3,80	2,50		V
	10	20		8,10		8,10	9,00	7,80		V
	15	20		13,10		13,10	14,00	12,80		V
Output voltage HIGH	5	25	V_{OH}				3,70			V
	10	25					8,90			V
	15	25					14,00			V

HEC	V_{DD} V	I_{OH} mA	SYMBOL	T_{amb} (°C) –55 MIN.	MAX.	+ 25 MIN.	TYP.	+ 125 MIN.	MAX.	
Output voltage	5	0		4,10		4,10	4,40	4,10		V
HIGH	10	0	V_{OH}	9,10		9,10	9,90	9,10		V
	15	0		14,10		14,10	14,40	14,40		V
Output voltage	5	5					4,30			V
HIGH	10	5	V_{OH}				9,30			V
	15	5					14,30			V
Output voltage	5	10		3,60		3,60	4,25	3,20		V
HIGH	10	10	V_{OH}	8,75		8,75	9,25	8,35		V
	15	10		13,75		13,75	14,25	13,35		V
Output voltage	5	15					4,20			V
HIGH	10	15	V_{OH}				9,20			V
	15	15					14,20			V
Output voltage	5	20		2,80		2,80	4,20	2,30		V
HIGH	10	20	V_{OH}	8,10		8,10	9,20	7,60		V
	15	20		13,10		13,10	14,20	12,60		V
Output voltage	5	25					4,15			V
HIGH	10	25	V_{OH}				9,20			V
	15	25					14,20			V

AC CHARACTERISTICS

V_{SS} = 0 V; T_{amb} = 25 °C; input transition times ≤ 20 ns

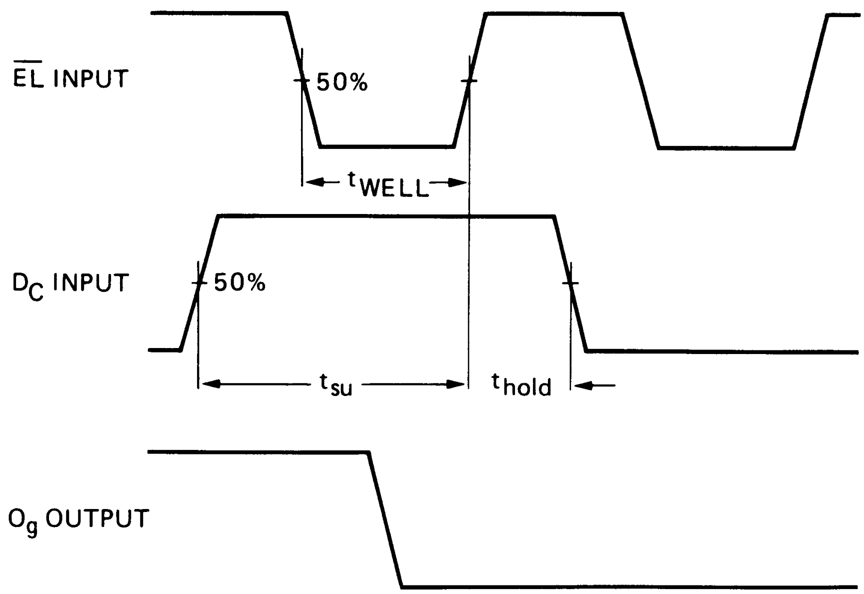
	V_{DD} V	TYPICAL FORMULA FOR P (μW)	
Dynamic power	5	$1\,000\ f_i + \Sigma\ (f_oC_L) \times V_{DD}^2$	where
dissipation per	10	$4\,000\ f_i + \Sigma\ (f_oC_L) \times V_{DD}^2$	f_i = input freq. (MHz)
package (P)	15	$10\,000\ f_i + \Sigma\ (f_oC_L) \times V_{DD}^2$	f_o = output freq. (MHz)
			C_L = load capacitance (pF)
			$\Sigma\ (f_oC_L)$ = sum of outputs
			V_{DD} = supply voltage (V)

AC CHARACTERISTICS

V_{SS} = 0 V; T_{amb} = 25 °C; C_L = 50 pF; input transition times ≤ 20 ns

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		TYPICAL EXTRAPOLATION FORMULA
Propagation delays							
$D_n \to O_n$	5			155	310	ns	128 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		60	120	ns	49 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
	5			135	270	ns	108 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		55	110	ns	44 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
$\overline{EL} \to O_n$	5			160	320	ns	133 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		60	120	ns	49 ns + (0,23 ns/pF) C_L
	15			45	90	ns	37 ns + (0,16 ns/pF) C_L
	5			160	320	ns	133 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		70	140	ns	59 ns + (0,23 ns/pF) C_L
	15			50	100	ns	42 ns + (0,16 ns/pF) C_L
$\overline{BI} \to O_n$	5			120	240	ns	93 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		50	100	ns	39 ns + (0,23 ns/pF) C_L
	15			35	70	ns	27 ns + (0,16 ns/pF) C_L
$\overline{BI} \to O_n$	5			105	210	ns	78 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		40	80	ns	29 ns + (0,23 ns/pF) C_L
	15			30	60	ns	22 ns + (0,16 ns/pF) C_L
$\overline{LT} \to O_n$	5			80	160	ns	52 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		30	60	ns	19 ns + (0,23 ns/pF) C_L
	15			20	40	ns	12 ns + (0,16 ns/pF) C_L
	5			60	120	ns	33 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		30	60	ns	19 ns + (0,23 ns/pF) C_L
	15			25	50	ns	17 ns + (0,16 ns/pF) C_L
Output transition times	5			60	120	ns	10 ns + (1,0 ns/pF) C_L
HIGH to LOW	10	t_{THL}		30	60	ns	9 ns + (0,42 ns/pF) C_L
	15			20	40	ns	6 ns + (0,28 ns/pF) C_L
	5			25	50	ns	20 ns + (1,0 na/pF) C_L
LOW to HIGH	10	t_{TLH}		16	32	ns	13 ns + (0,06 ns/pF) C_L
	15			13	26	ns	10 ns + (0,06 ns/pF) C_L

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		TYPICAL EXTRAPOLATION FORMULA
Minimum $\overline{EL}$	5		80	40		ns	see also waveforms Fig.8
pulse width; LOW	10	t_{WELL}	40	20		ns	
	15		35	17		ns	
Set-up time	5		50	25		ns	
$D_n \rightarrow \overline{EL}$	10	t_{su}	25	12		ns	
	15		20	9		ns	
Hold-time	5		60	30		ns	
$D_n \rightarrow \overline{EL}$	10	t_{hold}	30	15		ns	
	15		25	12		ns	



Conditions:
D_D = LOW
$D_A = D_B = \overline{B_I} = \overline{LT}$ = HIGH

Fig.8 Waveforms showing minimum $\overline{EL}$ pulse width, set-up and hold time for DC to $\overline{EL}$.

APPLICATION INFORMATION

Some examples of applications for the HEF4511B are:

- Driving LED displays.
- Driving incandescent displays.
- Driving fluorescent displays.
- Driving LCD displays.
- Driving gas discharge displays.

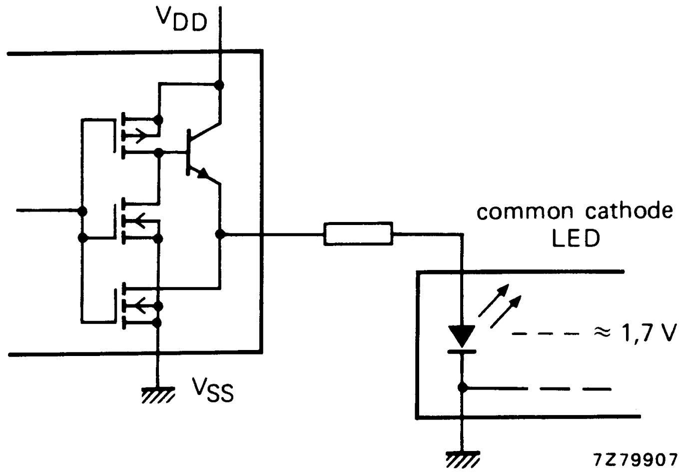


Fig.9 Connection to common cathode LED display readout.

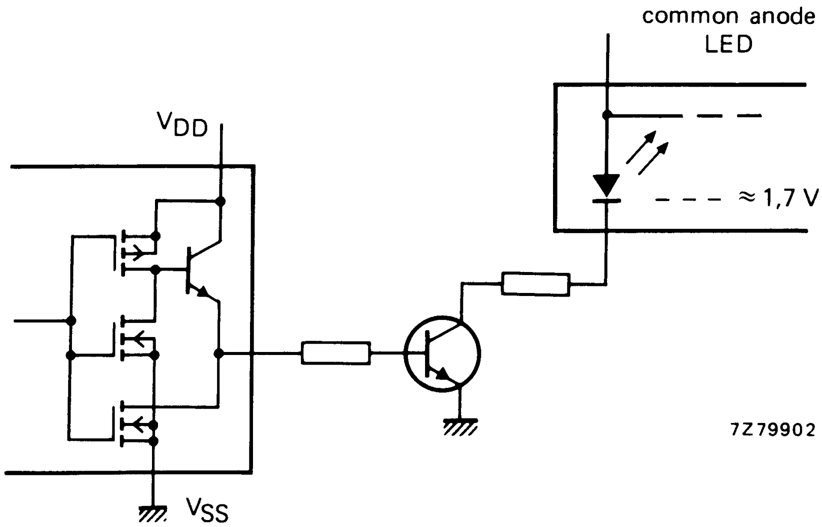
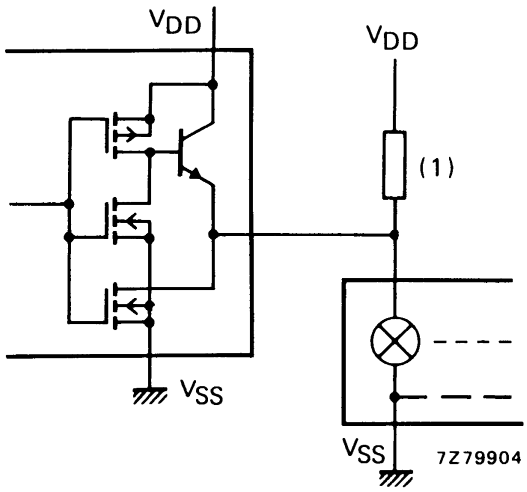


Fig.10 Connection to common anode LED display readout.



(1) A filament pre-warm resistor is recommended to reduce filament thermal shock and increase the effective cold resistance of the filament.

Fig.11 Connection to incandescent display readout.

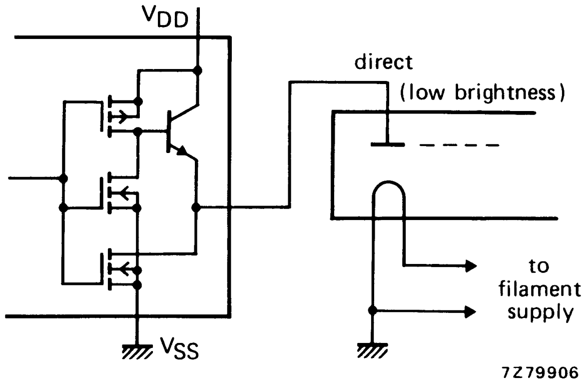


Fig.12 Connection to fluorescent display readout.

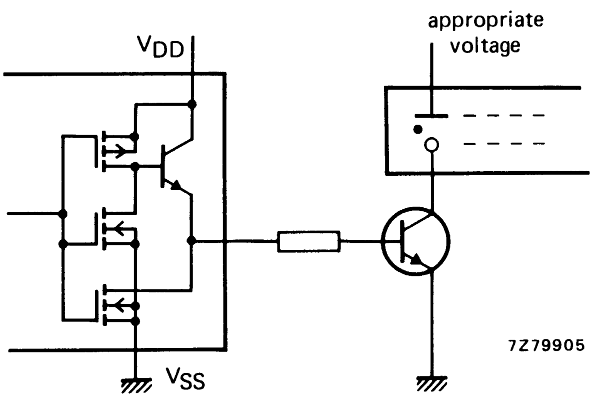


Fig.13 Connection to gas discharge display readout.

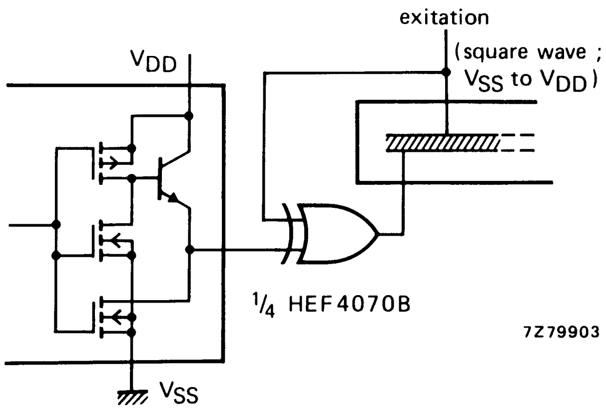
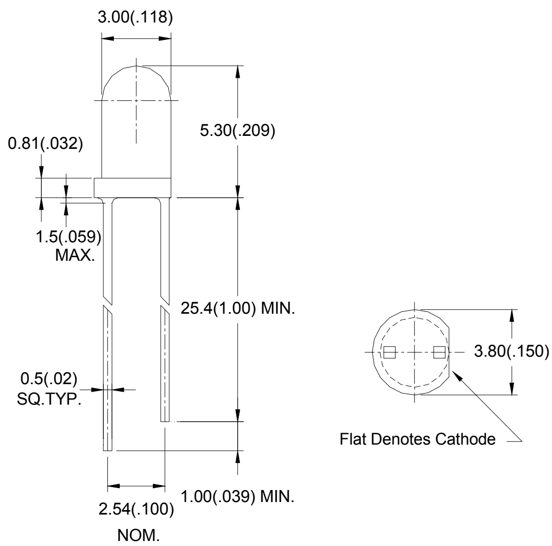


Fig.14 Connection to liquid crystal (LCD) display readout. Direct d.c. drive of LCDs not recommended for life of LCD readouts.

Features:

1. Chip material: GaP/GaP
2. Emitted color : Green
3. Lens Appearance : Green diffused
4. Low power consumption.
5. High efficiency.
6. Versatile mounting on P.C. Board or panel.
7. Low current requirement.
8. 3mm diameter package.
9. This product don't contained restriction substance, compliance ROHS standard.

Package dimensions



Notes:

1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25mm (0.01") unless otherwise specified.
3. Lead spacing is measured where the leads emerge from the package.
4. Specifications are subject to change without notice.

Applications:

1. TV set
2. Monitor
3. Telephone
4. Computer
5. Circuit board

Absolute Maximum Ratings(Ta=25℃)

Parameter	Symbol	Rating	Unit
Power Dissipation	Pd	80	mW
Forward Current	I_F	30	mA
Peak Forward Current*[1]	I_{FP}	150	mA
Reverse Voltage	V_R	5	V
Operating Temperature	Topr	-40℃~80℃	
Storage Temperature	Tstg	-40℃~85℃	
Soldering Temperature	Tsol	260℃(for 5 seconds)	

*[1]Condition for I_{FP} is pulse of 1/10 duty and 0.1msec width.

Electrical and optical characteristics(Ta=25℃)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=20mA	-	2.2	2.6	V
Luminous Intensity	Iv	I_F=20mA	-	40	-	mcd
Reverse Current	I_R	V_R=5V	-	-	100	μA
Peak Wave Length	λp	I_F=20mA	-	568	-	nm
Dominant Wave Length	λd	I_F=20mA	560	-	576	nm
Spectral Line Half-width	Δλ	I_F=20mA	-	30	-	nm
Viewing Angle	$2\theta_{1/2}$	I_F=20mA	-	35	-	deg

Typical electro-optical characteristics curves

Fig.1 Relative intensity vs. Wavelength

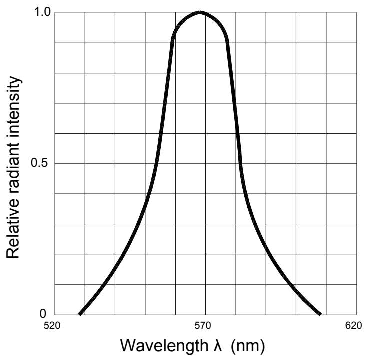


Fig.2 Forward current derating curve vs. Ambient temperature

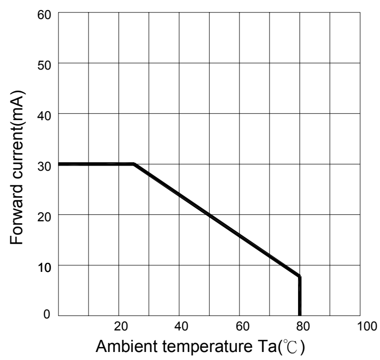


Fig.3 Forward current vs. Forward voltage

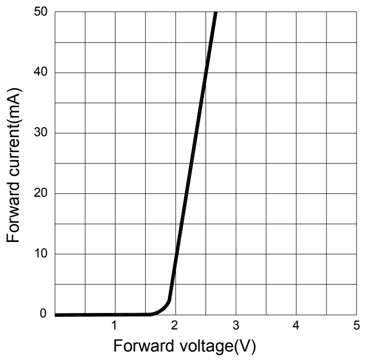


Fig.4 Relative luminous intensity vs. Ambient temperature

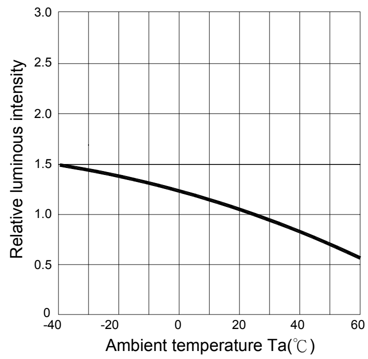


Fig.5 Relative luminous intensity vs. Forward current

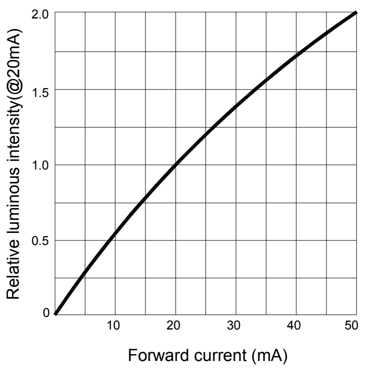
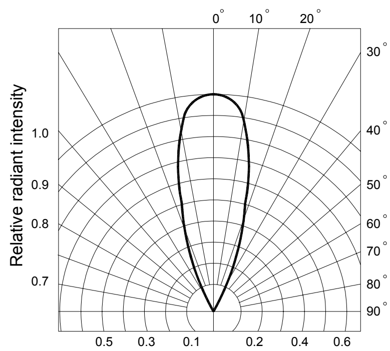


Fig.6 Radiation diagram



LM2676

LM2676 SIMPLE SWITCHER High Efficiency 3A Step-Down Voltage Regulator

Literature Number: SNVS031H

National Semiconductor

February 29, 2008

LM2676
SIMPLE SWITCHER® High Efficiency 3A Step-Down Voltage Regulator

General Description

The LM2676 series of regulators are monolithic integrated circuits which provide all of the active functions for a step-down (buck) switching regulator capable of driving up to 3A loads with excellent line and load regulation characteristics. High efficiency (>90%) is obtained through the use of a low ON-resistance DMOS power switch. The series consists of fixed output voltages of 3.3V, 5V and 12V and an adjustable output version.

The SIMPLE SWITCHER concept provides for a complete design using a minimum number of external components. A high fixed frequency oscillator (260KHz) allows the use of physically smaller sized components. A family of standard inductors for use with the LM2676 are available from several manufacturers to greatly simplify the design process.

The LM2676 series also has built in thermal shutdown, current limiting and an ON/OFF control input that can power down the regulator to a low 50µA quiescent current standby condition. The output voltage is guaranteed to a ±2% tolerance. The clock frequency is controlled to within a ±11% tolerance.

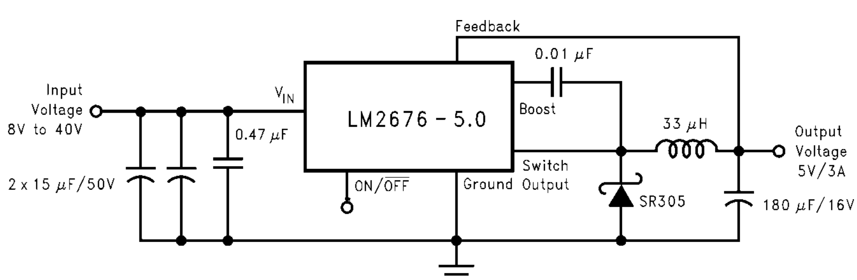
Features

- Efficiency up to 94%
- Simple and easy to design with (using off-the-shelf external components)
- 150 mΩ DMOS output switch
- 3.3V, 5V and 12V fixed output and adjustable (1.2V to 37V) versions
- 50µA standby current when switched OFF
- ±2%maximum output tolerance over full line and load conditions
- Wide input voltage range: 8V to 40V
- 260 KHz fixed frequency internal oscillator
- −40 to +125°C operating junction temperature range

Applications

- Simple to design, high efficiency (>90%) step-down switching regulators
- Efficient system pre-regulator for linear voltage regulators
- Battery chargers

Typical Application



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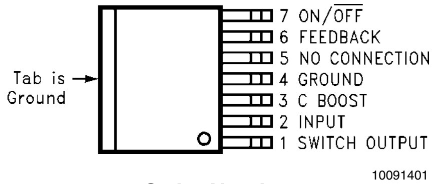
SIMPLE SWITCHER® is a registered trademark of National Semiconductor Corporation

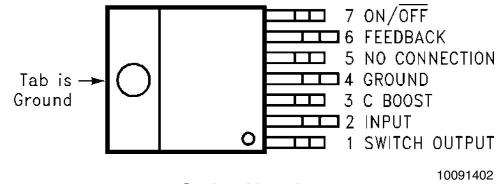
Connection Diagrams and Ordering Information

TO-263 Package
Top View



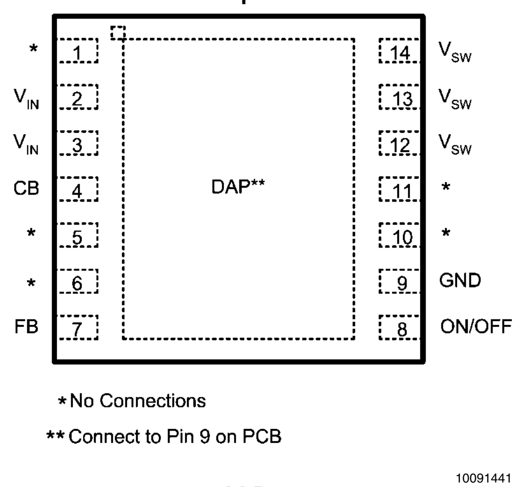
Order Number
LM2676S-3.3, LM2676S-5.0,
LM2676S-12 or LM2676S-ADJ
See NSC Package Number TS7B

TO-220 Package
Top View



Order Number
LM2676T-3.3, LM2676T-5.0,
LM2676T-12 or LM2676T-ADJ
See NSC Package Number TA07B

Top View



LLP-14
See NS package Number SRC14A

Ordering Information for LLP Package

Output Voltage	Order Information	Package Marking	Supplied As
12	LM2676SD-12	S0003LB	250 Units on Tape and Reel
12	LM2676SDX-12	S0003LB	2500 Units on Tape and Reel
3.3	LM2676SD-3.3	S0003NB	250 Units on Tape and Reel
3.3	LM2676SDX-3.3	S0003NB	2500 Units on Tape and Reel
5.0	LM2676SD-5.0	S0003PB	250 Units on Tape and Reel
5.0	LM2676SDX-5.0	S0003PB	2500 Units on Tape and Reel
ADJ	LM2676SD-ADJ	S0003RB	250 Units on Tape and Reel
ADJ	LM2676SDX-ADJ	S0003RB	2500 Units on Tape and Reel

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Supply Voltage	45V
ON/OFF Pin Voltage	−0.1V to 6V
Switch Voltage to Ground (Note 12)	−1V to V_{IN}
Boost Pin Voltage	V_{SW} + 8V
Feedback Pin Voltage	−0.3V to 14V
Power Dissipation	Internally Limited
ESD (Note 2)	2 kV
Storage Temperature Range	−65°C to 150°C
Soldering Temperature	
Wave	4 sec, 260°C
Infrared	10 sec, 240°C
Vapor Phase	75 sec, 219°C

Operating Ratings

Supply Voltage	8V to 40V
Junction Temperature Range (T_J)	−40°C to 125°C

Electrical Characteristics

Limits appearing in **bold type face** apply over the entire junction temperature range of operation, −40°C to 125°C. Specifications appearing in normal type apply for $T_A = T_J = 25°C$.

LM2676-3.3

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 3A	3.3	3.234/**3.201**	3.366/**3.399**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	86			%

LM2676-5.0

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 3A	5.0	4.900/**4.850**	5.100/**5.150**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	88			%

LM2676-12

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 15V to 40V, 100mA ≤ I_{OUT} ≤ 3A	12	11.76/**11.64**	12.24/**12.36**	V
η	Efficiency	V_{IN} = 24V, I_{LOAD} = 3A	94			%

LM2676-ADJ

Symbol	Parameter	Conditions	Typ (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{FB}	Feedback Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 3A V_{OUT} Programmed for 5V	1.21	1.186/**1.174**	1.234/**1.246**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	88			%

All Output Voltage Versions Electrical Characteristics

Limits appearing in **bold type face** apply over the entire junction temperature range of operation, −40°C to 125°C.

Specifications appearing in normal type apply for $T_A = T_J = 25°C$. Unless otherwise specified V_{IN}=12V for the 3.3V, 5V and Adjustable versions and V_{IN}=24V for the 12V version.

Symbol	Parameter	Conditions	Typ	Min	Max	Units
DEVICE PARAMETERS						
I_Q	Quiescent Current	$V_{FEEDBACK}$ = 8V For 3.3V, 5.0V, and ADJ Versions $V_{FEEDBACK}$ = 15V For 12V Versions	4.2		6	mA
I_{STBY}	Standby Quiescent Current	ON/OFF Pin = 0V	50		100/**150**	μA
I_{CL}	Current Limit		4.5	3.8/**3.6**	5.25/**5.4**	A
I_L	Output Leakage Current	V_{IN} = 40V, ON/OFF Pin = 0V V_{SWITCH} = 0V V_{SWITCH} = −1V	 16		 200 15	μA mA
$R_{DS(ON)}$	Switch On-Resistance	I_{SWITCH} = 3A	0.15		0.17/**0.29**	Ω
f_O	Oscillator Frequency	Measured at Switch Pin	260	**225**	**280**	kHz
D	Duty Cycle	Maximum Duty Cycle Minimum Duty Cycle	91 0			% %
I_{BIAS}	Feedback Bias Current	$V_{FEEDBACK}$ = 1.3V ADJ Version Only	85			nA
$V_{ON/OFF}$	ON/OFF Threshold Voltage		1.4	**0.8**	**2.0**	V
$I_{ON/OFF}$	ON/OFF Input Current	ON/OFF Input = 0V	20		**45**	μA
θ_{JA}	Thermal Resistance	T Package, Junction to Ambient (Note 5)	65			°C/W
θ_{JA}		T Package, Junction to Ambient (Note 6)	45			
θ_{JC}		T Package, Junction to Case	2			
θ_{JA}		S Package, Junction to Ambient (Note 7)	56			
θ_{JA}		S Package, Junction to Ambient (Note 8)	35			
θ_{JA}		S Package, Junction to Ambient (Note 9)	26			
θ_{JC}		S Package, Junction to Case	2			++
θ_{JA}		SD Package, Junction to Ambient (Note 10)	55			°C/W
θ_{JA}		SD Package, Junction to Ambient (Note 11)	29			

Note 1: Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings indicate conditions under which of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test condition, see the electrical Characteristics tables.

Note 2: ESD was applied using the human-body model, a 100pF capacitor discharged through a 1.5 kΩ resistor into each pin.

Note 3: Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

Note 4: All limits are guaranteed at room temperature (standard type face) and at **temperature extremes (bold type face)**. All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are guaranteed via correlation using standard standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Note 5: Junction to ambient thermal resistance (no external heat sink) for the 7 lead TO-220 package mounted vertically, with ½ inch leads in a socket, or on a PC board with minimum copper area.

Note 6: Junction to ambient thermal resistance (no external heat sink) for the 7 lead TO-220 package mounted vertically, with ½ inch leads soldered to a PC board containing approximately 4 square inches of (1 oz.) copper area surrounding the leads.

Note 7: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board area of 0.136 square inches (the same size as the TO-263 package) of 1 oz. (0.0014 in. thick) copper.

Note 8: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board area of 0.4896 square inches (3.6 times the area of the TO-263 package) of 1 oz. (0.0014 in. thick) copper.

Note 9: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board copper area of 1.0064 square inches (7.4 times the area of the TO-263 package) of 1 oz. (0.0014 in. thick) copper. Additional copper area will reduce thermal resistance further. See the thermal model in Switchers Made Simple® software.

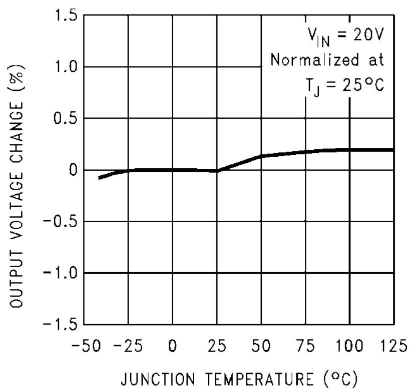
Note 10: Junction to ambient thermal resistance for the 14-lead LLP mounted on a PC board copper area equal to the die attach paddle.

Note 11: Junction to ambient thermal resistance for the 14-lead LLP mounted on a PC board copper area using 12 vias to a second layer of copper equal to die attach paddle. Additional copper area will reduce thermal resistance further. For layout recommendations, refer to Application Note AN-1187.

Note 12: The absolute maximum specification of the 'Switch Voltage to Ground' applies to DC voltage. An extended negative voltage limit of -8V applies to a pulse of up to 20 ns, -6V of 60 ns and -3V of up to 100 ns.

Typical Performance Characteristics

Normalized Output Voltage



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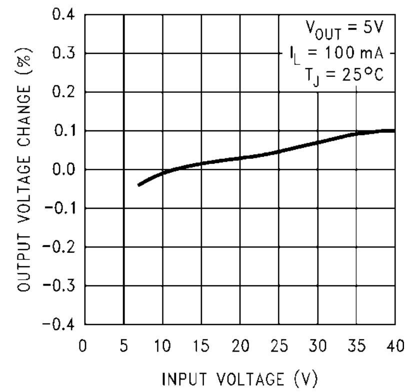
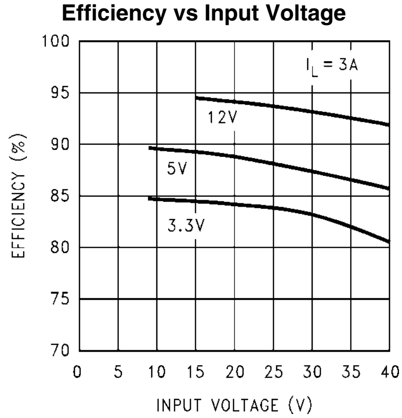
Line Regulation



10091410

Efficiency vs Input Voltage



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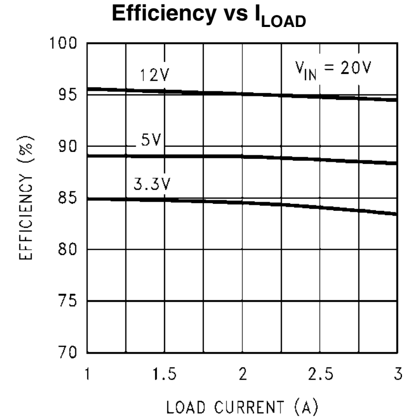
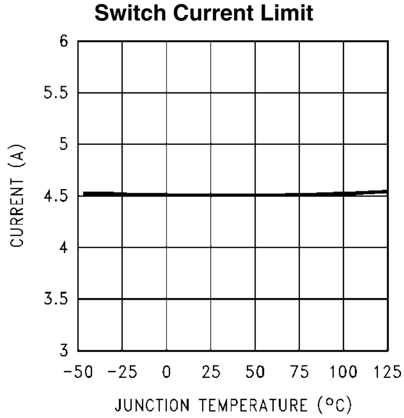
Efficiency vs I_{LOAD}



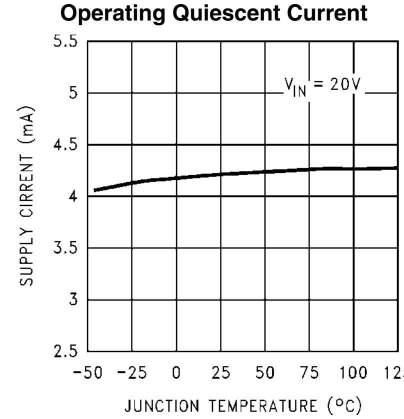
10091412

Switch Current Limit



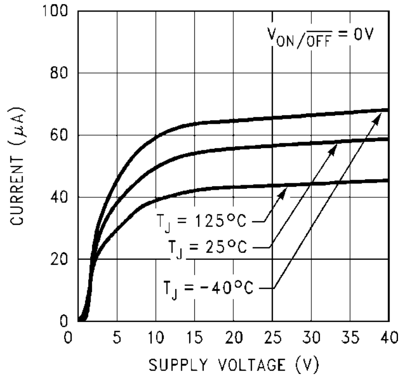
10091404

Operating Quiescent Current



10091405

Standby Quiescent Current



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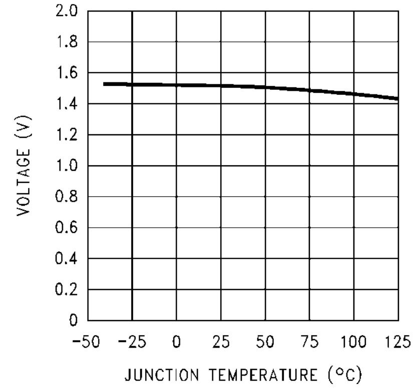
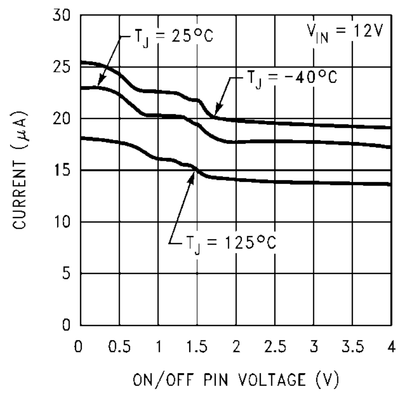
ON/OFF Threshold Voltage



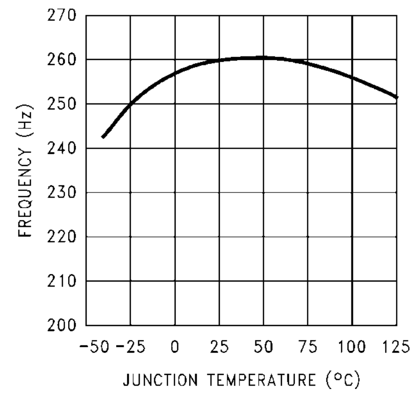
10091413

ON/OFF Pin Current (Sourcing)



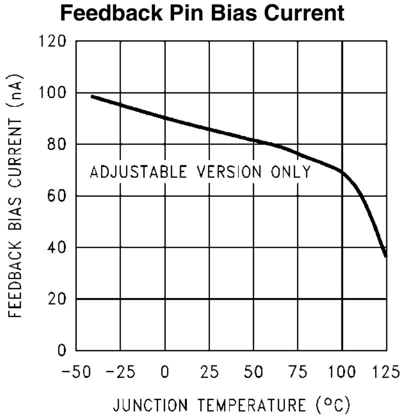
10091414

Switching Frequency



10091415

Feedback Pin Bias Current



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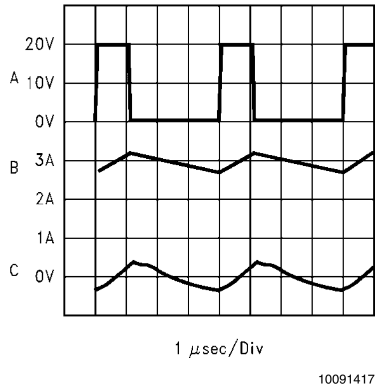
Typical Performance Characteristics

Continuous Mode Switching Waveforms
V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 3A
L = 33 µH, C_{OUT} = 200 µF, C_{OUT}ESR = 26 mΩ



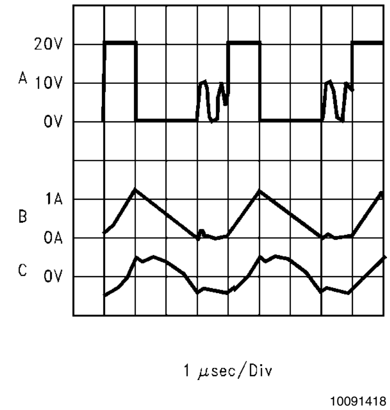
A: V_{SW} Pin Voltage, 10 V/div.

B: Inductor Current, 1 A/div

C: Output Ripple Voltage, 20 mV/div AC-Coupled

Horizontal Time Base: 1 µs/div

Discontinuous Mode Switching Waveforms
V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 500 mA
L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ



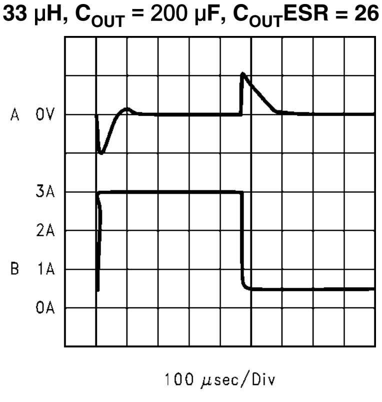
A: V_{SW} Pin Voltage, 10 V/div.

B: Inductor Current, 1 A/div

C: Output Ripple Voltage, 20 mV/div AC-Coupled

Horizontal Time Base: 1 µs//iv

Load Transient Response for Continuous Mode
V_{IN} = 20V, V_{OUT} = 5V
L = 33 µH, C_{OUT} = 200 µF, C_{OUT}ESR = 26 mΩ

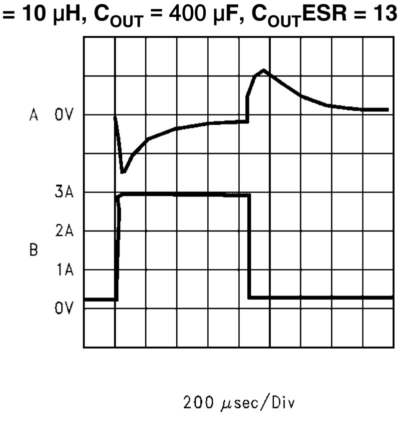


A: Output Voltage, 100 mV//div, AC-Coupled.

B: Load Current: 500 mA to 3A Load Pulse

Horizontal Time Base: 100 µs/div

Load Transient Response for Discontinuous Mode
V_{IN} = 20V, V_{OUT} = 5V,
L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ

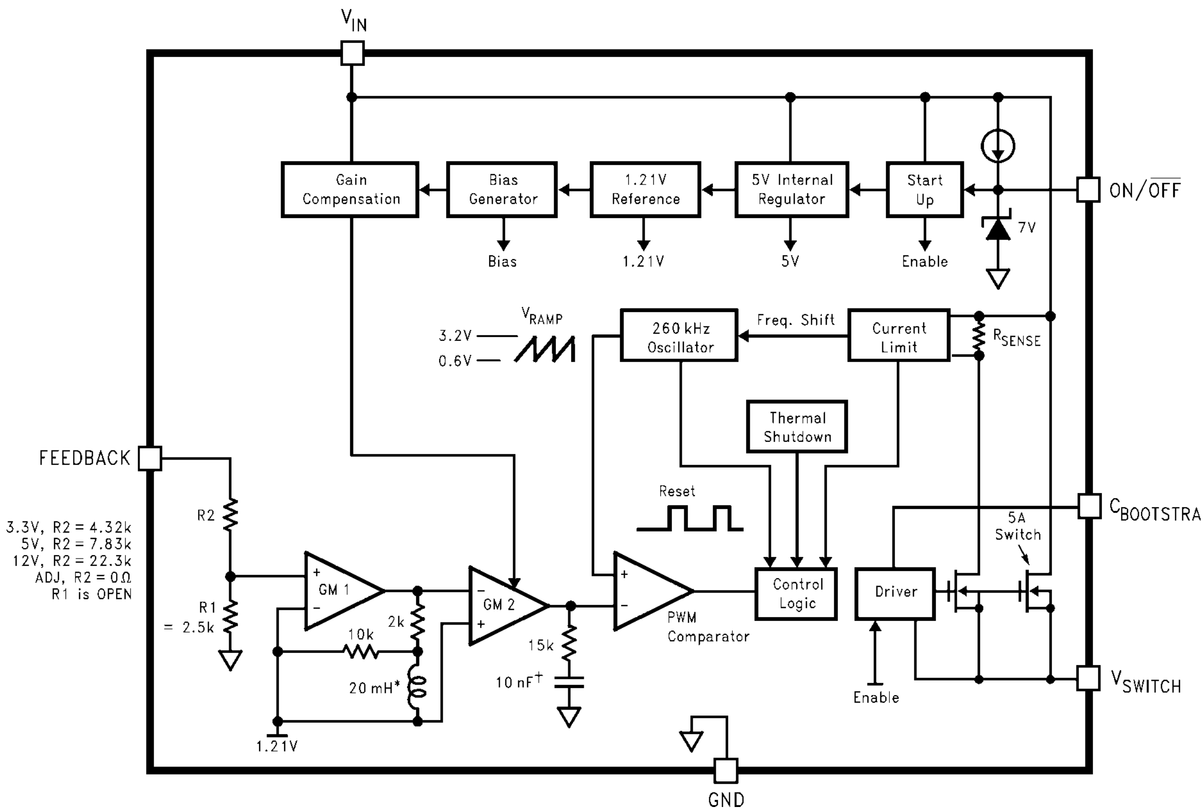


A: Output Voltage, 100 mV/div, AC-Coupled.

B: Load Current: 200 mA to 3A Load Pulse

Horizontal Time Base: 200 µs/div

Block Diagram



* Active Inductor Patent Number 5,514,947

† Active Capacitor Patent Number 5,382,918

Application Hints

The LM2676 provides all of the active functions required for a step-down (buck) switching regulator. The internal power switch is a DMOS power MOSFET to provide power supply designs with high current capability, up to 3A, and highly efficient operation.

The LM2676 is part of the ***SIMPLE SWITCHER*** family of power converters. A complete design uses a minimum number of external components, which have been pre-determined from a variety of manufacturers. Using either this data sheet or a design software program called ***LM267X Made Simple*** (version 2.0) a complete switching power supply can be designed quickly. The software is provided free of charge and can be downloaded from National Semiconductor's Internet site located at http://www.national.com.

SWITCH OUTPUT

This is the output of a power MOSFET switch connected directly to the input voltage. The switch provides energy to an inductor, an output capacitor and the load circuitry under control of an internal pulse-width-modulator (PWM). The PWM controller is internally clocked by a fixed 260KHz oscillator. In a standard step-down application the duty cycle (Time ON/ Time OFF) of the power switch is proportional to the ratio of the power supply output voltage to the input voltage. The voltage on pin 1 switches between Vin (switch ON) and below ground by the voltage drop of the external Schottky diode (switch OFF).

INPUT

The input voltage for the power supply is connected to pin 2. In addition to providing energy to the load the input voltage also provides bias for the internal circuitry of the LM2676. For guaranteed performance the input voltage must be in the range of 8V to 40V. For best performance of the power supply the input pin should always be bypassed with an input capacitor located close to pin 2.

C BOOST

A capacitor must be connected from pin 3 to the switch output, pin 1. This capacitor boosts the gate drive to the internal MOSFET above Vin to fully turn it ON. This minimizes conduction losses in the power switch to maintain high efficiency. The recommended value for C Boost is 0.01µF.

GROUND

This is the ground reference connection for all components in the power supply. In fast-switching, high-current applications such as those implemented with the LM2676, it is recommended that a broad ground plane be used to minimize signal coupling throughout the circuit

FEEDBACK

This is the input to a two-stage high gain amplifier, which drives the PWM controller. It is necessary to connect pin 6 to the actual output of the power supply to set the dc output voltage. For the fixed output devices (3.3V, 5V and 12V outputs), a direct wire connection to the output is all that is required as internal gain setting resistors are provided inside the LM2676. For the adjustable output version two external resistors are required to set the dc output voltage. For stable operation of the power supply it is important to prevent coupling of any inductor flux to the feedback input.

ON/OFF

This input provides an electrical ON/OFF control of the power supply. Connecting this pin to ground or to any voltage less than 0.8V will completely turn OFF the regulator. The current drain from the input supply when OFF is only 50µA. Pin 7 has an internal pull-up current source of approximately 20µA and a protection clamp zener diode of 7V to ground. When electrically driving the ON/OFF pin the high voltage level for the ON condition should not exceed the 6V absolute maximum limit. When ON/OFF control is not required pin 7 should be left open circuited.

DAP (LLP PACKAGE)

The Die Attach Pad (DAP) can and should be connected to PCB Ground plane/island. For CAD and assembly guidelines refer to Application Note AN-1187 at http://power.national.com.

DESIGN CONSIDERATIONS

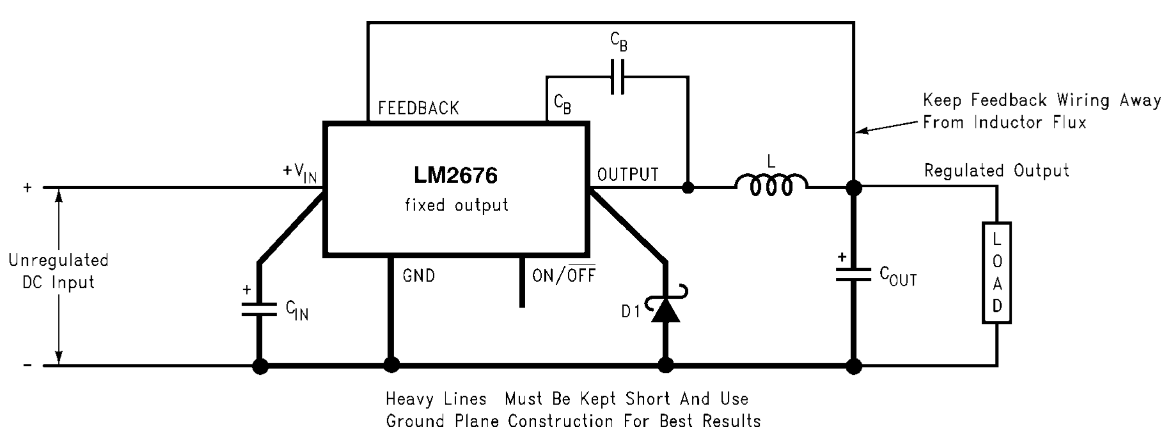


FIGURE 1. Basic circuit for fixed output voltage applications.

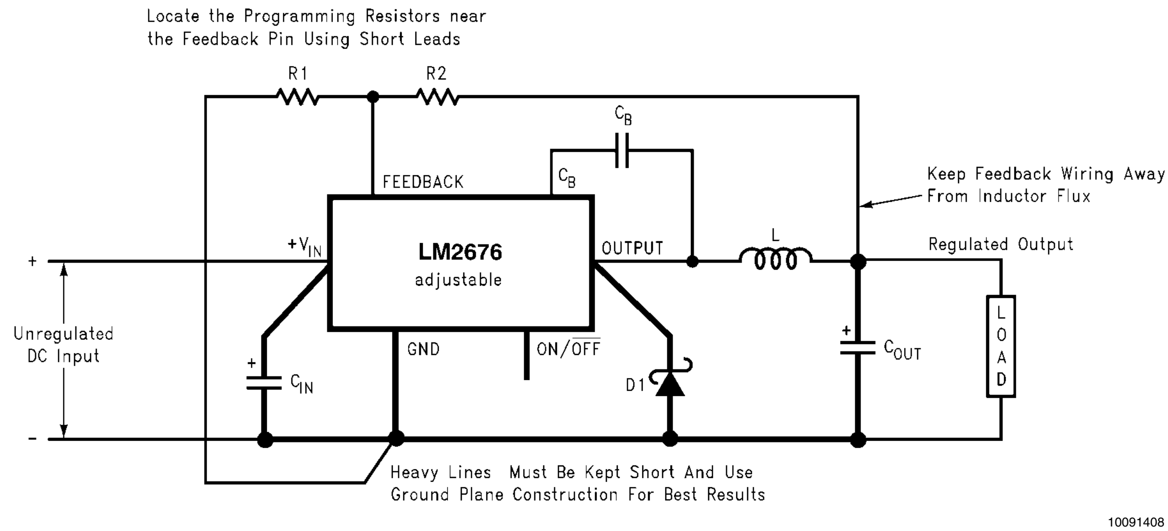


FIGURE 2. Basic circuit for adjustable output voltage applications

Power supply design using the LM2676 is greatly simplified by using recommended external components. A wide range of inductors, capacitors and Schottky diodes from several manufacturers have been evaluated for use in designs that cover the full range of capabilities (input voltage, output voltage and load current) of the LM2676. A simple design procedure using nomographs and component tables provided in this data sheet leads to a working design with very little effort. Alternatively, the design software, ***LM267X Made Simple*** (version 6.0), can also be used to provide instant component selection, circuit performance calculations for evaluation, a bill of materials component list and a circuit schematic.

The individual components from the various manufacturers called out for use are still just a small sample of the vast array of components available in the industry. While these components are recommended, they are not exclusively the only components for use in a design. After a close comparison of component specifications, equivalent devices from other manufacturers could be substituted for use in an application.

Important considerations for each external component and an explanation of how the nomographs and selection tables were developed follows.

INDUCTOR

The inductor is the key component in a switching regulator. For efficiency the inductor stores energy during the switch ON time and then transfers energy to the load while the switch is OFF.

Nomographs are used to select the inductance value required for a given set of operating conditions. The nomographs assume that the circuit is operating in continuous mode (the current flowing through the inductor never falls to zero). The magnitude of inductance is selected to maintain a maximum ripple current of 30% of the maximum load current. If the ripple current exceeds this 30% limit the next larger value is selected.

The inductors offered have been specifically manufactured to provide proper operation under all operating conditions of input and output voltage and load current. Several part types are offered for a given amount of inductance. Both surface mount and through-hole devices are available. The inductors from each of the three manufacturers have unique characteristics.

Renco: ferrite stick core inductors; benefits are typically lowest cost and can withstand ripple and transient peak currents above the rated value. These inductors have an external magnetic field, which may generate EMI.

Pulse Engineering: powdered iron toroid core inductors; these also can withstand higher than rated currents and, being toroid inductors, will have low EMI.

Coilcraft: ferrite drum core inductors; these are the smallest physical size inductors and are available only as surface mount components. These inductors also generate EMI but less than stick inductors.

OUTPUT CAPACITOR

The output capacitor acts to smooth the dc output voltage and also provides energy storage. Selection of an output capacitor, with an associated equivalent series resistance (ESR), impacts both the amount of output ripple voltage and stability of the control loop.

The output ripple voltage of the power supply is the product of the capacitor ESR and the inductor ripple current. The capacitor types recommended in the tables were selected for having low ESR ratings.

In addition, both surface mount tantalum capacitors and through-hole aluminum electrolytic capacitors are offered as solutions.

Impacting frequency stability of the overall control loop, the output capacitance, in conjunction with the inductor, creates a double pole inside the feedback loop. In addition the capacitance and the ESR value create a zero. These frequency response effects together with the internal frequency compensation circuitry of the LM2676 modify the gain and phase shift of the closed loop system.

As a general rule for stable switching regulator circuits it is desired to have the unity gain bandwidth of the circuit to be limited to no more than one-sixth of the controller switching frequency. With the fixed 260KHz switching frequency of the LM2676, the output capacitor is selected to provide a unity gain bandwidth of 40KHz maximum. Each recommended capacitor value has been chosen to achieve this result.

In some cases multiple capacitors are required either to reduce the ESR of the output capacitor, to minimize output ripple (a ripple voltage of 1% of Vout or less is the assumed performance condition), or to increase the output capacitance to reduce the closed loop unity gain bandwidth (to less than 40KHz). When parallel combinations of capacitors are required it has been assumed that each capacitor is the exact same part type.

The RMS current and working voltage (WV) ratings of the output capacitor are also important considerations. In a typical step-down switching regulator, the inductor ripple current (set to be no more than 30% of the maximum load current by the inductor selection) is the current that flows through the output capacitor. The capacitor RMS current rating must be greater than this ripple current. The voltage rating of the output capacitor should be greater than 1.3 times the maximum output voltage of the power supply. If operation of the system at elevated temperatures is required, the capacitor voltage rating may be de-rated to less than the nominal room temperature rating. Careful inspection of the manufacturer's specification for de-rating of working voltage with temperature is important.

INPUT CAPACITOR

Fast changing currents in high current switching regulators place a significant dynamic load on the unregulated power source. An input capacitor helps to provide additional current to the power supply as well as smooth out input voltage variations.

Like the output capacitor, the key specifications for the input capacitor are RMS current rating and working voltage. The RMS current flowing through the input capacitor is equal to one-half of the maximum dc load current so the capacitor should be rated to handle this. Paralleling multiple capacitors proportionally increases the current rating of the total capacitance. The voltage rating should also be selected to be 1.3 times the maximum input voltage. Depending on the unregulated input power source, under light load conditions the maximum input voltage could be significantly higher than normal operation and should be considered when selecting an input capacitor.

The input capacitor should be placed very close to the input pin of the LM2676. Due to relative high current operation with fast transient changes, the series inductance of input connecting wires or PCB traces can create ringing signals at the input terminal which could possibly propagate to the output or other parts of the circuitry. It may be necessary in some designs to add a small valued (0.1µF to 0.47µF) ceramic type capacitor in parallel with the input capacitor to prevent or minimize any ringing.

CATCH DIODE

When the power switch in the LM2676 turns OFF, the current through the inductor continues to flow. The path for this current is through the diode connected between the switch output and ground. This forward biased diode clamps the switch output to a voltage less than ground. This negative voltage must be greater than −1V so a low voltage drop (particularly at high current levels) Schottky diode is recommended. Total efficiency of the entire power supply is significantly impacted by the power lost in the output catch diode. The average current through the catch diode is dependent on the switch duty cycle (D) and is equal to the load current times (1-D). Use of a diode rated for much higher current than is required by the actual application helps to minimize the voltage drop and power loss in the diode.

During the switch ON time the diode will be reversed biased by the input voltage. The reverse voltage rating of the diode should be at least 1.3 times greater than the maximum input voltage.

BOOST CAPACITOR

The boost capacitor creates a voltage used to overdrive the gate of the internal power MOSFET. This improves efficiency by minimizing the on resistance of the switch and associated power loss. For all applications it is recommended to use a 0.01µF/50V ceramic capacitor.

ADDITIONAL APPLICATON INFORMATION

When the output voltage is greater than approximately 6V, and the duty cycle at minimum input voltage is greater than approximately 50%, the designer should exercise caution in selection of the output filter components. When an application designed to these specific operating conditions is subjected to a current limit fault condition, it may be possible to observe a large hysteresis in the current limit. This can affect the output voltage of the device until the load current is reduced sufficiently to allow the current limit protection circuit to reset itself.

Under current limiting conditions, the LM267x is designed to respond in the following manner:

1. At the moment when the inductor current reaches the current limit threshold, the ON-pulse is immediately terminated. This happens for any application condition.
2. However, the current limit block is also designed to momentarily reduce the duty cycle to below 50% to avoid subharmonic oscillations, which could cause the inductor to saturate.
3. Thereafter, once the inductor current falls below the current limit threshold, there is a small relaxation time during which the duty cycle progressively rises back above 50% to the value required to achieve regulation.

If the output capacitance is sufficiently 'large', it may be possible that as the output tries to recover, the output capacitor charging current is large enough to repeatedly re-trigger the current limit circuit before the output has fully settled. This condition is exacerbated with higher output voltage settings because the energy requirement of the output capacitor varies as the square of the output voltage ($\frac{1}{2}CV^2$), thus requiring an increased charging current.

A simple test to determine if this condition might exist for a suspect application is to apply a short circuit across the output of the converter, and then remove the shorted output condition. In an application with properly selected external components, the output will recover smoothly.

Practical values of external components that have been experimentally found to work well under these specific operating conditions are C_{OUT} = 47µF, L = 22µH. It should be noted that even with these components, for a device's current limit of I_{CLIM}, the maximum load current under which the possibility of the large current limit hysteresis can be minimized is $I_{CLIM}/2$. For example, if the input is 24V and the set output voltage is 18V, then for a desired maximum current of 1.5A, the current limit of the chosen switcher must be confirmed to be at least 3A.

SIMPLE DESIGN PROCEDURE

Using the nomographs and tables in this data sheet (or use the available design software at http://www.national.com) a complete step-down regulator can be designed in a few simple steps.

Step 1: Define the power supply operating conditions:

Required output voltage

Maximum DC input voltage

Maximum output load current

Step 2: Set the output voltage by selecting a fixed output LM2676 (3.3V, 5V or 12V applications) or determine the required feedback resistors for use with the adjustable LM2676 –ADJ

Step 3: Determine the inductor required by using one of the four nomographs, *Figure 3* through *Figure 6*. Table 1 provides a specific manufacturer and part number for the inductor.

Step 4: Using Table 3 (fixed output voltage) or Table 6 (adjustable output voltage), determine the output capacitance required for stable operation. Table 2 provides the specific capacitor type from the manufacturer of choice.

Step 5: Determine an input capacitor from Table 4 for fixed output voltage applications. Use Table 2 to find the specific capacitor type. For adjustable output circuits select a capacitor from Table 2 with a sufficient working voltage (WV) rating greater than Vin max, and an rms current rating greater than one-half the maximum load current (2 or more capacitors in parallel may be required).

Step 6: Select a diode from Table 5. The current rating of the diode must be greater than I load max and the Reverse Voltage rating must be greater than Vin max.

Step 7: Include a 0.01µF/50V capacitor for Cboost in the design.

FIXED OUTPUT VOLTAGE DESIGN EXAMPLE

A system logic power supply bus of 3.3V is to be generated from a wall adapter which provides an unregulated DC voltage of 13V to 16V. The maximum load current is 2.5A. Through-hole components are preferred.

Step 1: Operating conditions are:

Vout = 3.3V

Vin max = 16V

Iload max = 2.5A

Step 2: Select an LM2676T-3.3. The output voltage will have a tolerance of

±2% at room temperature and ±3% over the full operating temperature range.

Step 3: Use the nomograph for the 3.3V device ,*Figure 3*. The intersection of the 16V horizontal line (V_{in} max) and the 2.5A vertical line (I_{load} max) indicates that L33, a 22µH inductor, is required.

From Table 1, L33 in a through-hole component is available from Renco with part number RL-1283-22-43 or part number PE-53933 from Pulse Engineering.

Step 4: Use Table 3 to determine an output capacitor. With a 3.3V output and a 22µH inductor there are four through-hole output capacitor solutions with the number of same type capacitors to be paralleled and an identifying capacitor code given. Table 2 provides the actual capacitor characteristics. Any of the following choices will work in the circuit:

1 x 220µF/10V Sanyo OS-CON (code C5)

1 x 1000µF/35V Sanyo MV-GX (code C10)

1 x 2200µF/10V Nichicon PL (code C5)

1 x 1000µF/35V Panasonic HFQ (code C7)

Step 5: Use Table 4 to select an input capacitor. With 3.3V output and 22µH there are three through-hole solutions. These capacitors provide a sufficient voltage rating and an rms current rating greater than 1.25A (1/2 I_{load} max). Again using Table 2 for specific component characteristics the following choices are suitable:

1 x 1000µF/63V Sanyo MV-GX (code C14)

1 x 820µF/63V Nichicon PL (code C24)

1 x 560µF/50V Panasonic HFQ (code C13)

Step 6: From Table 5 a 3A Schottky diode must be selected. For through-hole components 20V rated diodes are sufficient and 2 part types are suitable:

1N5820

SR302

Step 7: A 0.01µF capacitor will be used for Cboost.

ADJUSTABLE OUTPUT DESIGN EXAMPLE

In this example it is desired to convert the voltage from a two battery automotive power supply (voltage range of 20V to 28V, typical in large truck applications) to the 14.8VDC alternator supply typically used to power electronic equipment from single battery 12V vehicle systems. The load current required is 2A maximum. It is also desired to implement the power supply with all surface mount components.

Step 1: Operating conditions are:

Vout = 14.8V

Vin max = 28V

Iload max = 2A

Step 2: Select an LM2676S-ADJ. To set the output voltage to 14.9V two resistors need to be chosen (R1 and R2 in *Figure 2*). For the adjustable device the output voltage is set by the following relationship:

$$V_{OUT} = V_{FB}\left(1 + \frac{R_2}{R_1}\right)$$

Where V_{FB} is the feedback voltage of typically 1.21V.

A recommended value to use for R1 is 1K. In this example then R2 is determined to be:

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{FB}} - 1\right) = 1\,k\Omega\left(\frac{14.8V}{1.21V} - 1\right)$$

R2 = 11.23KΩ

The closest standard 1% tolerance value to use is 11.3KΩ

This will set the nominal output voltage to 14.88V which is within 0.5% of the target value.

Step 3: To use the nomograph for the adjustable device, *Figure 6*, requires a calculation of the inductor Volt•microsecond constant (E•T expressed in V•µS) from the following formula:

$$E \cdot T = (V_{IN(MAX)} - V_{OUT} - V_{SAT}) \cdot \frac{V_{OUT} + V_D}{V_{IN(MAX)} - V_{SAT} + V_D} \cdot \frac{1000}{260}\ (V \cdot \mu s)$$

where V_{SAT} is the voltage drop across the internal power switch which is $R_{ds(ON)}$ times I_{load}. In this example this would be typically 0.15Ω x 2A or 0.3V and V_D is the voltage drop across the forward bisased Schottky diode, typically 0.5V. The switching frequency of 260KHz is the nominal value to use to estimate the ON time of the switch during which energy is stored in the inductor.

For this example E•T is found to be:

$$E \cdot T = (28 - 14.8 - 0.3) \cdot \frac{14.8 + 0.5}{28 - 0.3 + 0.5} \cdot \frac{1000}{260}\ (V \cdot \mu s)$$

$$E \cdot T = (12.9V) \cdot \frac{15.3}{28.2} \cdot 3.85\ (V \cdot \mu s) = 26.9\ (V \cdot \mu s)$$

Using *Figure 6*, the intersection of 27V•µS horizontally and the 2A vertical line (I_{load} max) indicates that L38 , a 68µH inductor, should be used.

From Table 1, L38 in a surface mount component is available from Pulse Engineering with part number PE-54038S.

Step 4: Use Table 6 to determine an output capacitor. With a 14.8V output the 12.5 to 15V row is used and with a 68µH inductor there are three surface mount output capacitor solutions. Table 2 provides the actual capacitor characteristics based on the C Code number. Any of the following choices can be used:

1 x 33µF/20V AVX TPS (code C6)

1 x 47µF/20V Sprague 594 (code C8)

1 x 47µF/20V Kemet T495 (code C8)

Important Note: When using the adjustable device in low voltage applications (less than 3V output), if the nomograph, Figure 6, selects an inductance of 22µH or less, Table 6 does not provide an output capacitor solution. With these conditions the number of output capacitors required for stable operation becomes impractical. It is recommended to use either a 33µH or 47µH inductor and the output capacitors from Table 6.

Step 5: An input capacitor for this example will require at least a 35V WV rating with an rms current rating of 1A (1/2 Iout max). From Table 2 it can be seen that C12, a 33µF/35V capacitor from Sprague, has the required voltage/current rating of the surface mount components.

Step 6: From Table 5 a 3A Schottky diode must be selected. For surface mount diodes with a margin of safety on the voltage rating one of five diodes can be used:

SK34

30BQ040

30WQ04F

MBRS340

MBRD340

Step 7: A 0.01µF capacitor will be used for Cboost.

LLP PACKAGE DEVICES

The LM2676 is offered in the 14 lead LLP surface mount package to allow for a significantly decreased footprint with equivalent power dissipation compared to the TO-263. For details on mounting and soldering specifications, refer to Application Note AN-1187.

Inductor Selection Guides

For Continuous Mode Operation

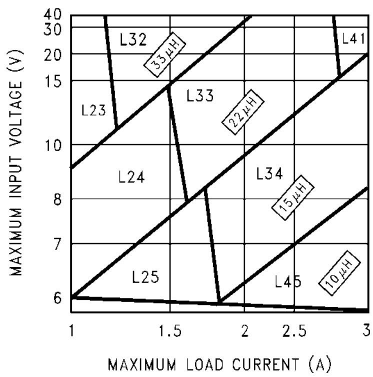


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FIGURE 3. LM2676-3.3

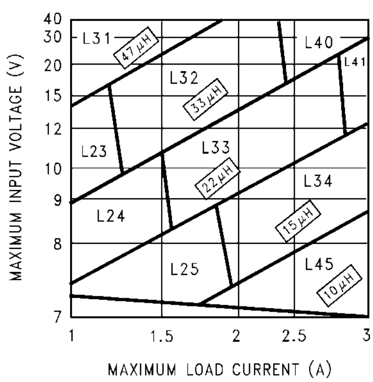

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FIGURE 4. LM2676-5.0

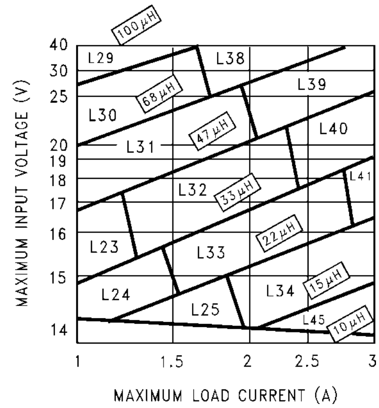

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FIGURE 5. LM2676-12

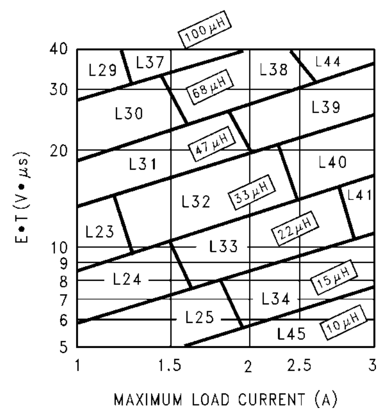

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FIGURE 6. LM2676-ADJ

Table 1. Inductor Manufacturer Part Numbers

Inductor Reference Number	Inductance (µH)	Current (A)	Renco		Pulse Engineering		Coilcraft
			Through Hole	Surface Mount	Through Hole	Surface Mount	Surface Mount
L23	33	1.35	RL-5471-7	RL1500-33	PE-53823	PE-53823S	DO3316-333
L24	22	1.65	RL-1283-22-43	RL1500-22	PE-53824	PE-53824S	DO3316-223
L25	15	2.00	RL-1283-15-43	RL1500-15	PE-53825	PE-53825S	DO3316-153
L29	100	1.41	RL-5471-4	RL-6050-100	PE-53829	PE-53829S	DO5022P-104
L30	68	1.71	RL-5471-5	RL6050-68	PE-53830	PE-53830S	DO5022P-683
L31	47	2.06	RL-5471-6	RL6050-47	PE-53831	PE-53831S	DO5022P-473
L32	33	2.46	RL-5471-7	RL6050-33	PE-53932	PE-53932S	DO5022P-333
L33	22	3.02	RL-1283-22-43	RL6050-22	PE-53933	PE-53933S	DO5022P-223
L34	15	3.65	RL-1283-15-43	—	PE-53934	PE-53934S	DO5022P-153
L38	68	2.97	RL-5472-2	—	PE-54038	PE-54038S	—
L39	47	3.57	RL-5472-3	—	PE-54039	PE-54039S	—
L40	33	4.26	RL-1283-33-43	—	PE-54040	PE-54040S	—
L41	22	5.22	RL-1283-22-43	—	PE-54041	P0841	—
L44	68	3.45	RL-5473-3	—	PE-54044	—	—
L45	10	4.47	RL-1283-10-43	—	—	P0845	DO5022P-103HC

Inductor Manufacturer Contact Numbers

Coilcraft	Phone	(800) 322-2645
	FAX	(708) 639-1469
Coilcraft, Europe	Phone	+44 1236 730 595
	FAX	+44 1236 730 627
Pulse Engineering	Phone	(619) 674-8100
	FAX	(619) 674-8262
Pulse Engineering, Europe	Phone	+353 93 24 107
	FAX	+353 93 24 459
Renco Electronics	Phone	(800) 645-5828
	FAX	(516) 586-5562

Capacitor Selection Guides

Table 2. Input and Output Capacitor Codes

Capacitor Reference Code	Surface Mount								
	AVX TPS Series			Sprague 594D Series			Kemet T495 Series		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	330	6.3	1.15	120	6.3	1.1	100	6.3	0.82
C2	100	10	1.1	220	6.3	1.4	220	6.3	1.1
C3	220	10	1.15	68	10	1.05	330	6.3	1.1
C4	47	16	0.89	150	10	1.35	100	10	1.1
C5	100	16	1.15	47	16	1	150	10	1.1
C6	33	20	0.77	100	16	1.3	220	10	1.1
C7	68	20	0.94	180	16	1.95	33	20	0.78
C8	22	25	0.77	47	20	1.15	47	20	0.94
C9	10	35	0.63	33	25	1.05	68	20	0.94
C10	22	35	0.66	68	25	1.6	10	35	0.63
C11				15	35	0.75	22	35	0.63
C12				33	35	1	4.7	50	0.66
C13				15	50	0.9			

Input and Output Capacitor Codes (continued)

Capacitor Reference Code	Through Hole											
	Sanyo OS-CON SA Series			Sanyo MV-GX Series			Nichicon PL Series			Panasonic HFQ Series		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	47	6.3	1	1000	6.3	0.8	680	10	0.8	82	35	0.4
C2	150	6.3	1.95	270	16	0.6	820	10	0.98	120	35	0.44
C3	330	6.3	2.45	470	16	0.75	1000	10	1.06	220	35	0.76
C4	100	10	1.87	560	16	0.95	1200	10	1.28	330	35	1.01
C5	220	10	2.36	820	16	1.25	2200	10	1.71	560	35	1.4
C6	33	16	0.96	1000	16	1.3	3300	10	2.18	820	35	1.62
C7	100	16	1.92	150	35	0.65	3900	10	2.36	1000	35	1.73
C8	150	16	2.28	470	35	1.3	6800	10	2.68	2200	35	2.8
C9	100	20	2.25	680	35	1.4	180	16	0.41	56	50	0.36
C10	47	25	2.09	1000	35	1.7	270	16	0.55	100	50	0.5
C11				220	63	0.76	470	16	0.77	220	50	0.92
C12				470	63	1.2	680	16	1.02	470	50	1.44
C13				680	63	1.5	820	16	1.22	560	50	1.68
C14				1000	63	1.75	1800	16	1.88	1200	50	2.22
C15							220	25	0.63	330	63	1.42
C16							220	35	0.79	1500	63	2.51
C17							560	35	1.43			
C18							2200	35	2.68			
C19							150	50	0.82			
C20							220	50	1.04			
C21							330	50	1.3			
C22							100	63	0.75			
C23							390	63	1.62			
C24							820	63	2.22			
C25							1200	63	2.51			

Capacitor Manufacturer Contact Numbers

Nichicon	Phone	(847) 843-7500
	FAX	(847) 843-2798
Panasonic	Phone	(714) 373-7857
	FAX	(714) 373-7102
AVX	Phone	(845) 448-9411
	FAX	(845) 448-1943
Sprague/Vishay	Phone	(207) 324-4140
	FAX	(207) 324-7223
Sanyo	Phone	(619) 661-6322
	FAX	(619) 661-1055
Kemet	Phone	(864) 963-6300
	FAX	(864) 963-6521

Table 3. Output Capacitors for Fixed Output Voltage Application

Output Voltage (V)	Inductance (µH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.3	10	4	C2	3	C1	4	C4
	15	4	C2	3	C1	4	C4
	22	3	C2	2	C7	3	C4
	33	2	C2	2	C6	2	C4
5	10	4	C2	4	C6	4	C4
	15	3	C2	2	C7	3	C4
	22	3	C2	2	C7	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	1	C7	2	C4
12	10	4	C5	3	C6	5	C9
	15	3	C5	2	C7	4	C8
	22	2	C5	2	C6	3	C8
	33	2	C5	1	C7	2	C8
	47	2	C4	1	C6	2	C8
	68	1	C5	1	C5	2	C7
	100	1	C4	1	C5	1	C8

Output Voltage (V)	Inductance (µH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.3	10	1	C3	1	C10	1	C6	2	C6
	15	1	C3	1	C10	1	C6	2	C5
	22	1	C5	1	C10	1	C5	1	C7
	33	1	C2	1	C10	1	C13	1	C5
5	10	2	C4	1	C10	1	C6	2	C5
	15	1	C5	1	C10	1	C5	1	C6
	22	1	C5	1	C5	1	C5	1	C5
	33	1	C4	1	C5	1	C13	1	C5
	47	1	C4	1	C4	1	C13	2	C3

Output Voltage (V)	Inductance (µH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
12	10	2	C7	1	C5	1	C18	2	C5
	15	1	C8	1	C5	1	C17	1	C5
	22	1	C7	1	C5	1	C13	1	C5
	33	1	C7	1	C3	1	C11	1	C4
	47	1	C7	1	C3	1	C10	1	C3
	68	1	C7	1	C2	1	C10	1	C3
	100	1	C7	1	C2	1	C9	1	C1

No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in Table 2 for identifying the specific component from the manufacturer.

Table 4. Input Capacitors for Fixed Output Voltage Application

(Assumes worst case maximum input voltage and load current for a given inductance value)

Output Voltage (V)	Inductance (µH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.3	10	2	C5	1	C7	2	C8
	15	3	C9	1	C10	3	C10
	22	*	*	2	C13	3	C12
	33	*	*	2	C13	2	C12
5	10	2	C5	1	C7	2	C8
	15	2	C5	1	C7	2	C8
	22	3	C10	2	C12	3	C11
	33	*	*	2	C13	3	C12
	47	*	*	1	C13	2	C12
12	10	2	C7	2	C10	2	C7
	15	2	C7	2	C10	2	C7
	22	3	C10	2	C12	3	C10
	33	3	C10	2	C12	3	C10
	47	*	*	2	C13	3	C12
	68	*	*	2	C13	2	C12
	100	*	*	1	C13	2	C12

Output Voltage (V)	Inductance (µH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.3	10	1	C7	2	C4	1	C5	1	C6
	15	1	C10	1	C10	1	C18	1	C6
	22	*	*	1	C14	1	C24	1	C13
	33	*	*	1	C12	1	C20	1	C12
5	10	1	C7	2	C4	1	C14	1	C6
	15	1	C7	2	C4	1	C14	1	C6
	22	*	*	1	C10	1	C18	1	C13
	33	*	*	1	C14	1	C23	1	C13
	47	*	*	1	C12	1	C20	1	C12

Output Voltage (V)	Inductance (µH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
12	10	1	C9	1	C10	1	C18	1	C6
	15	1	C10	1	C10	1	C18	1	C6
	22	1	C10	1	C10	1	C18	1	C6
	33	*	*	1	C10	1	C18	1	C6
	47	*	*	1	C13	1	C23	1	C13
	68	*	*	1	C12	1	C21	1	C12
	100	*	*	1	C11	1	C22	1	C11

* Check voltage rating of capacitors to be greater than application input voltage.
No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in Table 2 for identifying the specific component from the manufacturer.

Table 5. Schottky Diode Selection Table

Reverse Voltage (V)	Surface Mount		Through Hole	
	3A	5A or More	3A	5A or More
20V	SK32		1N5820 SR302	
30V	SK33 30WQ03F	MBRD835L	1N5821 31DQ03	
40V	SK34 30BQ040 30WQ04F MBRS340 MBRD340	MBRB1545CT 6TQ045S	1N5822 MBR340 31DQ04 SR403	MBR745 80SQ045 6TQ045
50V or More	SK35 30WQ05F		MBR350 31DQ05 SR305	

Diode Manufacturer Contact Numbers

International Rectifier	Phone	(310) 322-3331
	FAX	(310) 322-3332
Motorola	Phone	(800) 521-6274
	FAX	(602) 244-6609
General Semiconductor	Phone	(516) 847-3000
	FAX	(516) 847-3236
Diodes, Inc.	Phone	(805) 446-4800
	FAX	(805) 446-4850

Table 6. Output Capacitors for Adjustable Output Voltage Applications

Output Voltage (V)	Inductance (µH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
1.21 to 2.50	33*	7	C1	6	C2	7	C3
	47*	5	C1	4	C2	5	C3
2.5 to 3.75	33*	4	C1	3	C2	4	C3
	47*	3	C1	2	C2	3	C3

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.75 to 5	22	4	C1	3	C2	4	C3
	33	3	C1	2	C2	3	C3
	47	2	C1	2	C2	2	C3
5 to 6.25	22	3	C2	3	C3	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	2	C3	2	C4
	68	1	C2	1	C3	1	C4
6.25 to 7.5	22	3	C2	1	C4	3	C4
	33	2	C2	1	C3	2	C4
	47	1	C3	1	C4	1	C6
	68	1	C2	1	C3	1	C4
7.5 to 10	33	2	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C4	1	C5	1	C8
10 to 12.5	33	1	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C5	1	C6	1	C8
12.5 to 15	33	1	C6	1	C8	1	C8
	47	1	C6	1	C8	1	C8
	68	1	C6	1	C8	1	C8
	100	1	C6	1	C8	1	C8
15 to 20	33	1	C8	1	C10	2	C10
	47	1	C8	1	C9	2	C10
	68	1	C8	1	C9	2	C10
	100	1	C8	1	C9	1	C10
20 to 30	33	2	C9	2	C11	2	C11
	47	1	C10	1	C12	1	C11
	68	1	C9	1	C12	1	C11
	100	1	C9	1	C12	1	C11
30 to 37	10	No Values Available		4	C13	8	C12
	15			3	C13	5	C12
	22			2	C13	4	C12
	33			1	C13	3	C12
	47			1	C13	2	C12
	68			1	C13	2	C12

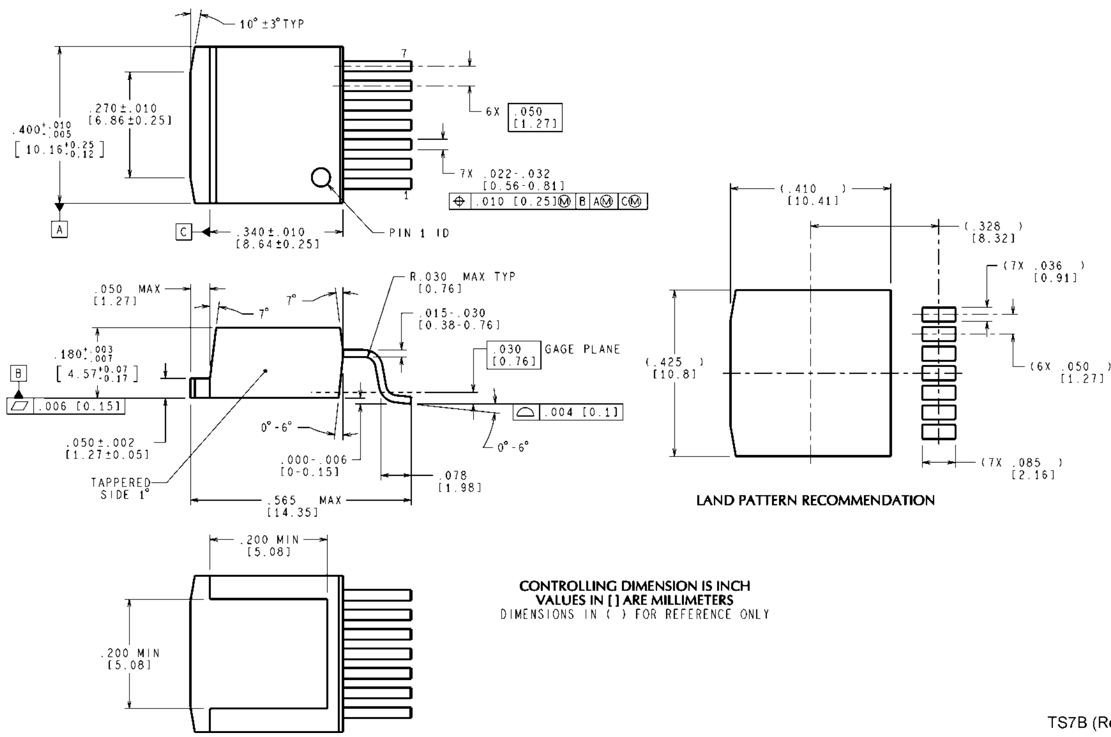
Output Capacitors for Adjustable Output Voltage Applications (continued)

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
1.21 to 2.50	33*	2	C3	5	C1	5	C3	3	C
	47*	2	C2	4	C1	3	C3	2	C5
2.5 to 3.75	33*	1	C3	3	C1	3	C1	2	C5
	47*	1	C2	2	C1	2	C3	1	C5

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.75 to 5	22	1	C3	3	C1	3	C1	2	C5
	33	1	C2	2	C1	2	C1	1	C5
	47	1	C2	2	C1	1	C3	1	C5
5 to 6.25	22	1	C5	2	C6	2	C3	2	C5
	33	1	C4	1	C6	2	C1	1	C5
	47	1	C4	1	C6	1	C3	1	C5
	68	1	C4	1	C6	1	C1	1	C5
6.25 to 7.5	22	1	C5	1	C6	2	C1	1	C5
	33	1	C4	1	C6	1	C3	1	C5
	47	1	C4	1	C6	1	C1	1	C5
	68	1	C4	1	C2	1	C1	1	C5
7.5 to 10	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C6	1	C14	1	C5
	68	1	C7	1	C2	1	C14	1	C2
	100	1	C7	1	C2	1	C14	1	C2
10 to 12.5	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C2	1	C14	1	C5
	68	1	C7	1	C2	1	C9	1	C2
	100	1	C7	1	C2	1	C9	1	C2
12.5 to 15	33	1	C9	1	C10	1	C15	1	C2
	47	1	C9	1	C10	1	C15	1	C2
	68	1	C9	1	C10	1	C15	1	C2
	100	1	C9	1	C10	1	C15	1	C2
15 to 20	33	1	C10	1	C7	1	C15	1	C2
	47	1	C10	1	C7	1	C15	1	C2
	68	1	C10	1	C7	1	C15	1	C2
	100	1	C10	1	C7	1	C15	1	C2
20 to 30	33	No Values Available		1	C7	1	C16	1	C2
	47			1	C7	1	C16	1	C2
	68			1	C7	1	C16	1	C2
	100			1	C7	1	C16	1	C2
30 to 37	10	No Values Available		1	C12	1	C20	1	C10
	15			1	C11	1	C20	1	C11
	22			1	C11	1	C20	1	C10
	33			1	C11	1	C20	1	C10
	47			1	C11	1	C20	1	C10
	68			1	C11	1	C20	1	C10

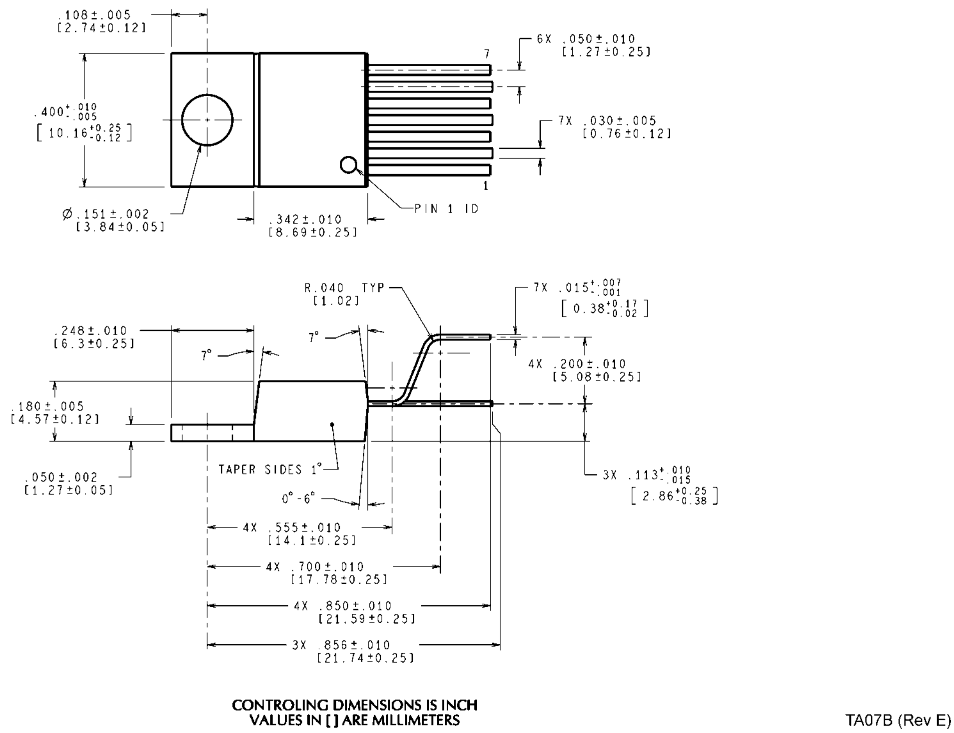
* Set to a higher value for a practical design solution. See Applications Hints section
No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in Table 2 for identifying the specific component from the manufacturer.

Physical Dimensions inches (millimeters) unless otherwise noted

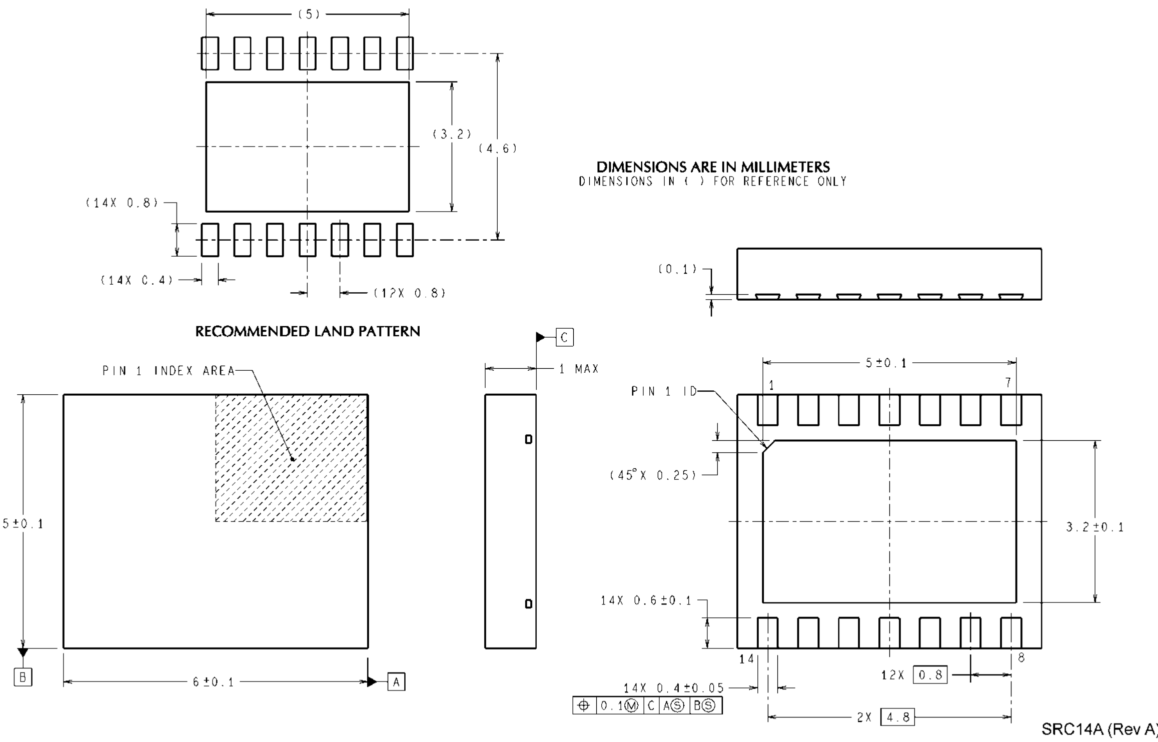


TS7B (Rev E)

TO-263 Surface Mount Power Package
Order Number LM2676S-3.3, LM2676S-5.0,
LM2676S-12 or LM2676S-ADJ
NS Package Number TS7B



TO-220 Power Package
Order Number LM2676T-3.3, LM2676T-5.0, LM2676T-12 or LM2676T-ADJ
NS Package Number TA07B



14-Lead LLP Package
NS Package Number SRC14A

Notes

Notes

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Texas Instruments

LM2676

SIMPLE SWITCHER®® High Efficiency 3A Step-Down Voltage Regulator

General Description

The LM2676 series of regulators are monolithic integrated circuits which provide all of the active functions for a step-down (buck) switching regulator capable of driving up to 3A loads with excellent line and load regulation characteristics. High efficiency (>90%) is obtained through the use of a low ON-resistance DMOS power switch. The series consists of fixed output voltages of 3.3V, 5V and 12V and an adjustable output version.

The SIMPLE SWITCHER concept provides for a complete design using a minimum number of external components. A high fixed frequency oscillator (260KHz) allows the use of physically smaller sized components. A family of standard inductors for use with the LM2676 are available from several manufacturers to greatly simplify the design process.

The LM2676 series also has built in thermal shutdown, current limiting and an ON/OFF control input that can power down the regulator to a low 50µA quiescent current standby condition. The output voltage is guaranteed to a ±2% tolerance. The clock frequency is controlled to within a ±11% tolerance.

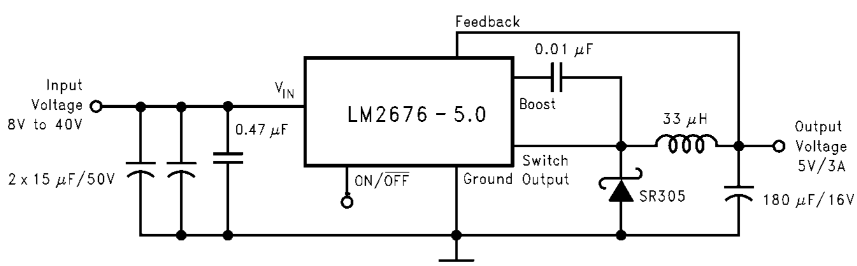
Features

- Efficiency up to 94%
- Simple and easy to design with (using off-the-shelf external components)
- 150 mΩ DMOS output switch
- 3.3V, 5V and 12V fixed output and adjustable (1.2V to 37V) versions
- 50µA standby current when switched OFF
- ±2%maximum output tolerance over full line and load conditions
- Wide input voltage range: 8V to 40V
- 260 KHz fixed frequency internal oscillator
- −40 to +125°C operating junction temperature range

Applications

- Simple to design, high efficiency (>90%) step-down switching regulators
- Efficient system pre-regulator for linear voltage regulators
- Battery chargers

Typical Application



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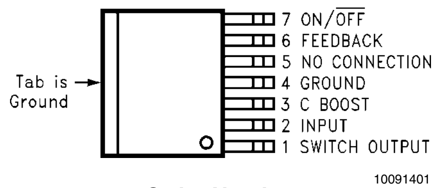
SIMPLE SWITCHER® is a registered trademark of National Semiconductor Corporation.

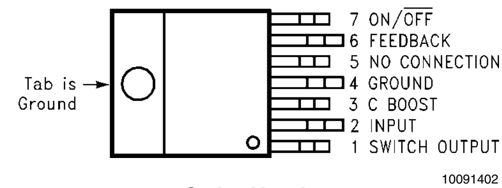
Connection Diagrams and Ordering Information

TO-263 Package
Top View



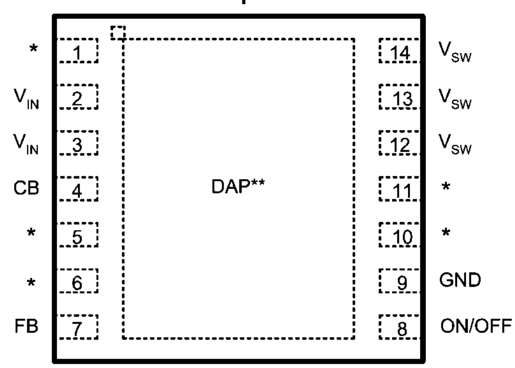
Order Number
LM2676-3.3,
LM2676S-12 or LM2676S-ADJ
See NSC Package Number TS7B

TO-220 Package
Top View



Order Number
LM2676T-3.3, LM2676T-5.0,
LM2676T-12 or LM2676T-ADJ
See NSC Package Number TA07B

Top View



*No Connections

**Connect to Pin 9 on PCB

10091441

LLP-14
See NS package Number SRC14A

Ordering Information for LLP Package

Output Voltage	Order Information	Package Marking	Supplied As
12	LM2676SD-12	S0003LB	250 Units on Tape and Reel
12	LM2676SDX-12	S0003LB	2500 Units on Tape and Reel
3.3	LM2676SD-3.3	S0003NB	250 Units on Tape and Reel
3.3	LM2676SDX-3.3	S0003NB	2500 Units on Tape and Reel
5.0	LM2676SD-5.0	S0003PB	250 Units on Tape and Reel
5.0	LM2676SDX-5.0	S0003PB	2500 Units on Tape and Reel
ADJ	LM2676SD-ADJ	S0003RB	250 Units on Tape and Reel
ADJ	LM2676SDX-ADJ	S0003RB	2500 Units on Tape and Reel

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.

Input Supply Voltage	45V
ON/OFF Pin Voltage	−0.1V to 6V
Switch Voltage to Ground (Note 12)	−1V to V_{IN}
Boost Pin Voltage	V_{SW} + 8V
Feedback Pin Voltage	−0.3V to 14V
Power Dissipation	Internally Limited
ESD (Note 2)	2 kV
Storage Temperature Range	−65°C to 150°C
Soldering Temperature	
Wave	4 sec, 260°C
Infrared	10 sec, 240°C
Vapor Phase	75 sec, 219°C

Operating Ratings

Supply Voltage	8V to 40V
Junction Temperature Range (T_J)	−40°C to 125°C

Electrical Characteristics

Limits appearing in **bold type face** apply over the entire junction temperature range of operation, −40°C to 125°C. Specifications appearing in normal type apply for $T_A = T_J = 25°C$.

LM2676-3.3

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 3A	3.3	3.234/**3.201**	3.366/**3.399**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	86			%

LM2676-5.0

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 3A	5.0	4.900/**4.850**	5.100/**5.150**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	88			%

LM2676-12

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 15V to 40V, 100mA ≤ I_{OUT} ≤ 3A	12	11.76/**11.64**	12.24/**12.36**	V
η	Efficiency	V_{IN} = 24V, I_{LOAD} = 3A	94			%

LM2676-ADJ

Symbol	Parameter	Conditions	Typ (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{FB}	Feedback Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 3A V_{OUT} Programmed for 5V	1.21	1.186/**1.174**	1.234/**1.246**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	88			%

All Output Voltage Versions

Electrical Characteristics

Limits appearing in **bold type face** apply over the entire junction temperature range of operation, −40°C to 125°C.

Specifications appearing in normal type apply for $T_A = T_J = 25°C$. Unless otherwise specified V_{IN}=12V for the 3.3V, 5V and Adjustable versions and V_{IN}=24V for the 12V version.

Symbol	Parameter	Conditions	Typ	Min	Max	Units
DEVICE PARAMETERS						
I_Q	Quiescent Current	$V_{FEEDBACK}$ = 8V For 3.3V, 5.0V, and ADJ Versions $V_{FEEDBACK}$ = 15V For 12V Versions	4.2		6	mA
I_{STBY}	Standby Quiescent Current	ON/OFF Pin = 0V	50		100/**150**	μA
I_{CL}	Current Limit		4.5	3.8/**3.6**	5.25/**5.4**	A
I_L	Output Leakage Current	V_{IN} = 40V, ON/OFF Pin = 0V V_{SWITCH} = 0V V_{SWITCH} = −1V	 16		 200 15	μA mA
$R_{DS(ON)}$	Switch On-Resistance	I_{SWITCH} = 3A	0.15		0.17/**0.29**	Ω
f_O	Oscillator Frequency	Measured at Switch Pin	260	**225**	**280**	kHz
D	Duty Cycle	Maximum Duty Cycle Minimum Duty Cycle	91 0			% %
I_{BIAS}	Feedback Bias Current	$V_{FEEDBACK}$ = 1.3V ADJ Version Only	85			nA
$V_{ON/OFF}$	ON/OFF Threshold Voltage		1.4	**0.8**	**2.0**	V
$I_{ON/OFF}$	ON/OFF Input Current	ON/OFF Input = 0V	20		**45**	μA
θ_{JA} θ_{JA} θ_{JC}	Thermal Resistance	T Package, Junction to Ambient (Note 5) T Package, Junction to Ambient (Note 6) T Package, Junction to Case	65 45 2			
θ_{JA} θ_{JA} θ_{JA} θ_{JC}		S Package, Junction to Ambient (Note 7) S Package, Junction to Ambient (Note 8) S Package, Junction to Ambient (Note 9) S Package, Junction to Case	56 35 26 2			°C/W ++
θ_{JA} θ_{JA}		SD Package, Junction to Ambient (Note 10) SD Package, Junction to Ambient (Note 11)	55 29			°C/W

Note 1: Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings indicate conditions under which of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test condition, see the electrical Characteristics tables.

Note 2: ESD was applied using the human-body model, a 100pF capacitor discharged through a 1.5 kΩ resistor into each pin.

Note 3: Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

Note 4: All limits are guaranteed at room temperature (standard type face) and at **temperature extremes (bold type face)**. All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are guaranteed via correlation using standard standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Note 5: Junction to ambient thermal resistance (no external heat sink) for the 7 lead TO-220 package mounted vertically, with ½ inch leads in a socket, or on a PC board with minimum copper area.

Note 6: Junction to ambient thermal resistance (no external heat sink) for the 7 lead TO-220 package mounted vertically, with ½ inch leads soldered to a PC board containing approximately 4 square inches of (1 oz.) copper area surrounding the leads.

Note 7: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board area of 0.136 square inches (the same size as the TO-263 package) of 1 oz. (0.0014 in. thick) copper.

Note 8: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board area of 0.4896 square inches (3.6 times the area of the TO-263 package) of 1 oz. (0.0014 in. thick) copper.

Note 9: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board copper area of 1.0064 square inches (7.4 times the area of the TO-263 package) of 1 oz. (0.0014 in. thick) copper. Additional copper area will reduce thermal resistance further. See the thermal model in Switchers Made Simple® software.

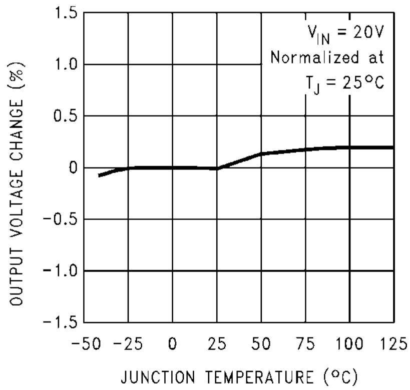
Note 10: Junction to ambient thermal resistance for the 14-lead LLP mounted on a PC board copper area equal to the die attach paddle.

Note 11: Junction to ambient thermal resistance for the 14-lead LLP mounted on a PC board copper area using 12 vias to a second layer of copper equal to die attach paddle. Additional copper area will reduce thermal resistance further. For layout recommendations, refer to Application Note AN-1187.

Note 12: The absolute maximum specification of the 'Switch Voltage to Ground' applies to DC voltage. An extended negative voltage limit of -8V applies to a pulse of up to 20 ns, -6V of 60 ns and -3V of up to 100 ns.

Typical Performance Characteristics

Normalized Output Voltage



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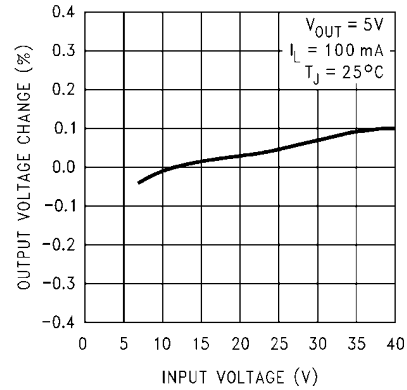
Line Regulation



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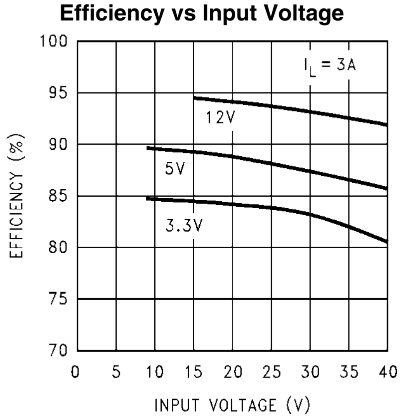
Efficiency vs Input Voltage



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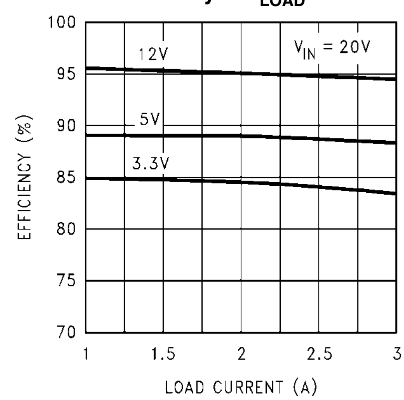
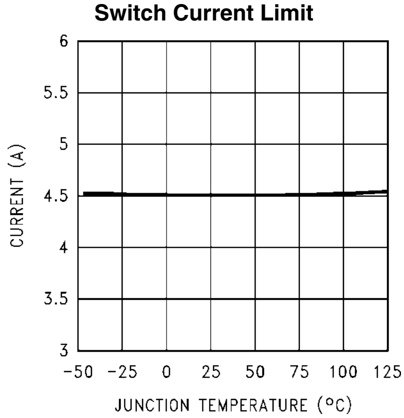
Efficiency vs I_{LOAD}



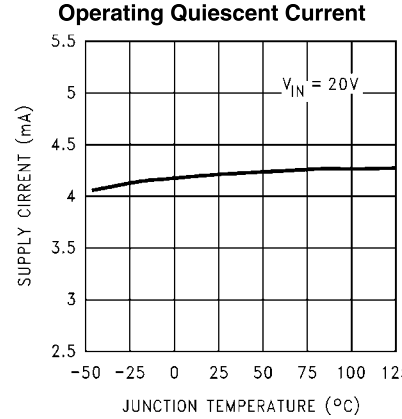
10091412

Switch Current Limit



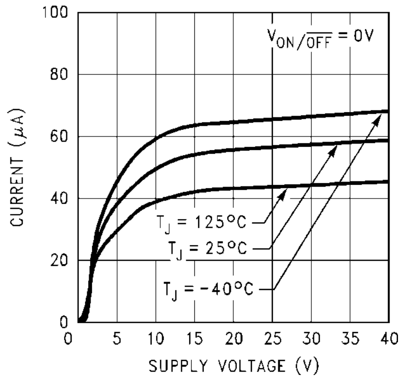
10091404

Operating Quiescent Current



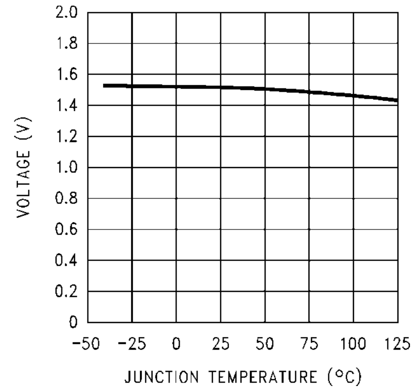
10091405

Standby Quiescent Current



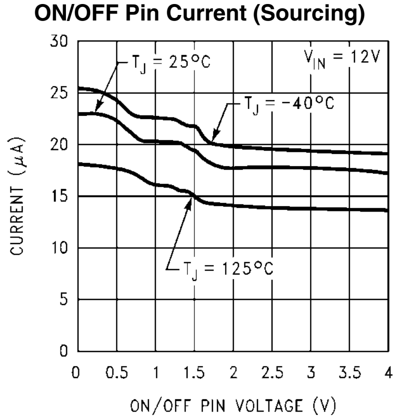
10091440

ON/OFF Threshold Voltage



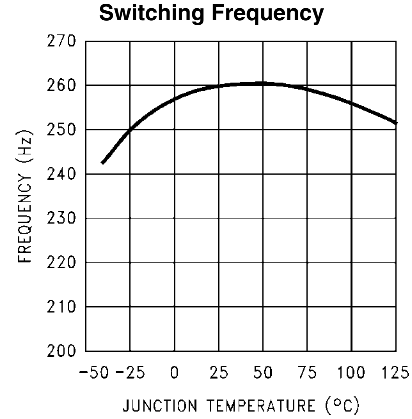
10091413

ON/OFF Pin Current (Sourcing)



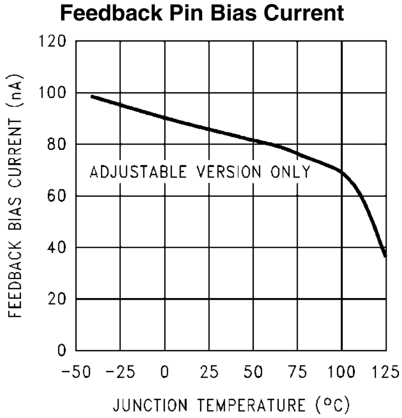
10091414

Switching Frequency



10091415

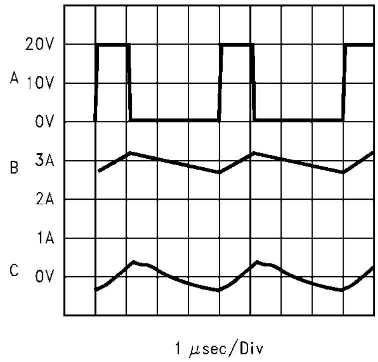
Feedback Pin Bias Current



10091416

Typical Performance Characteristics

Continuous Mode Switching Waveforms
V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 3A
L = 33 µH, C_{OUT} = 200 µF, C_{OUT}ESR = 26 mΩ

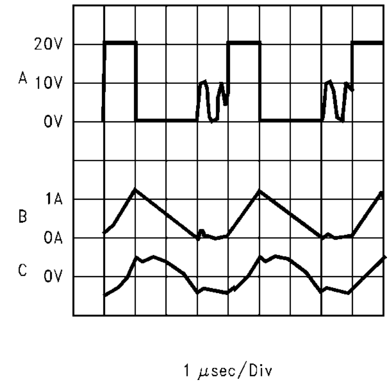


10091417

A: V_{SW} Pin Voltage, 10 V/div.
B: Inductor Current, 1 A/div
C: Output Ripple Voltage, 20 mV/div AC-Coupled

Horizontal Time Base: 1 µs/div

Discontinuous Mode Switching Waveforms
V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 500 mA
L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ

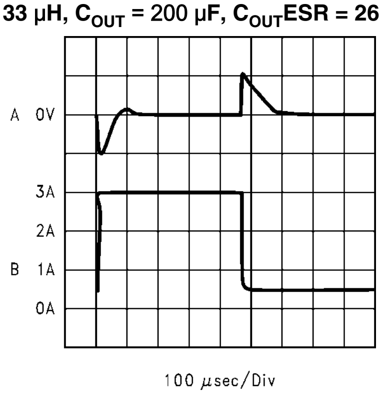


10091418

A: V_{SW} Pin Voltage, 10 V/div.
B: Inductor Current, 1 A/div
C: Output Ripple Voltage, 20 mV/div AC-Coupled

Horizontal Time Base: 1 µs//iv

Load Transient Response for Continuous Mode
V_{IN} = 20V, V_{OUT} = 5V
L = 33 µH, C_{OUT} = 200 µF, C_{OUT}ESR = 26 mΩ

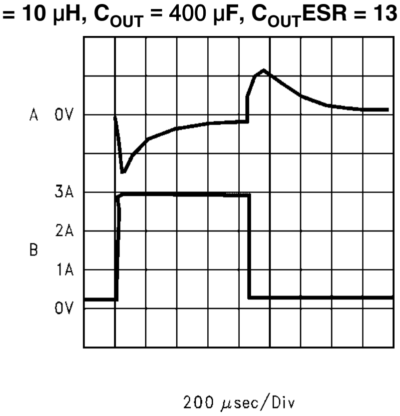


10091419

A: Output Voltage, 100 mV//div, AC-Coupled.
B: Load Current: 500 mA to 3A Load Pulse

Horizontal Time Base: 100 µs/div

Load Transient Response for Discontinuous Mode
V_{IN} = 20V, V_{OUT} = 5V,
L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ

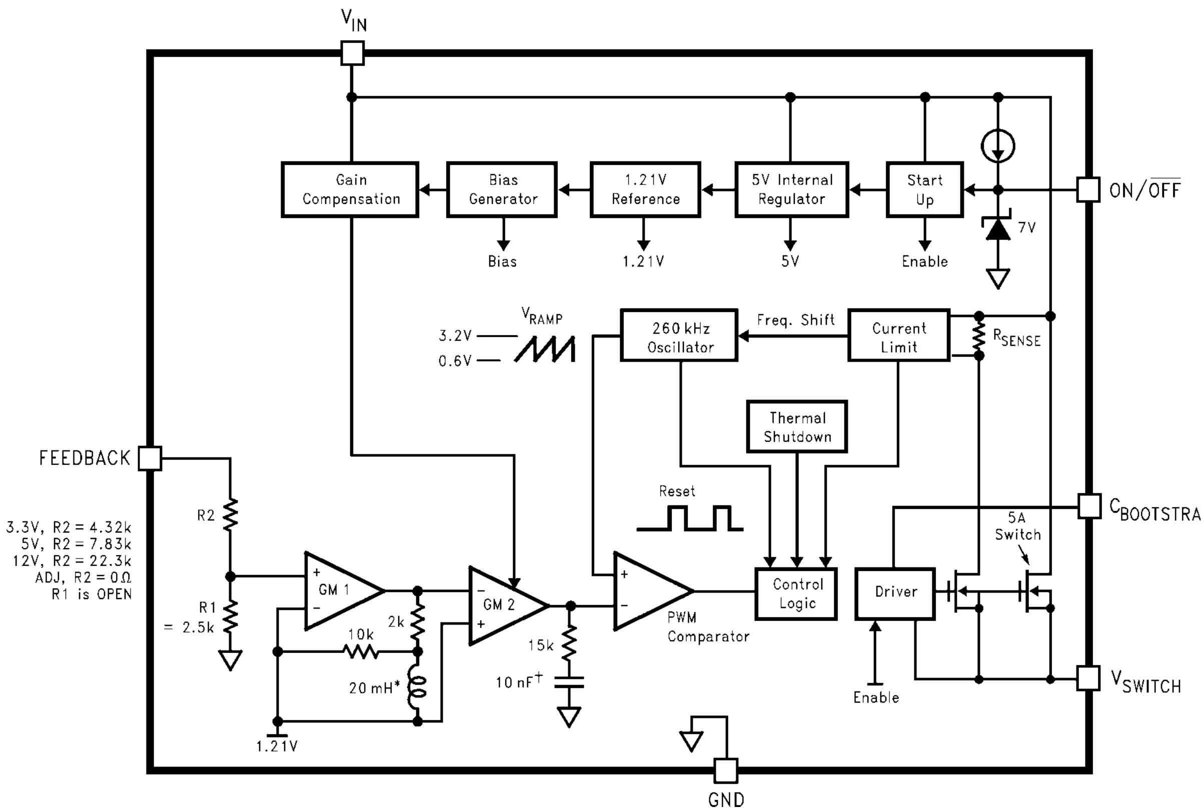


10091420

A: Output Voltage, 100 mV/div, AC-Coupled.
B: Load Current: 200 mA to 3A Load Pulse

Horizontal Time Base: 200 µs/div

Block Diagram



10091406

* Active Inductor Patent Number 5,514,947

† Active Capacitor Patent Number 5,382,918

Application Hints

The LM2676 provides all of the active functions required for a step-down (buck) switching regulator. The internal power switch is a DMOS power MOSFET to provide power supply designs with high current capability, up to 3A, and highly efficient operation.

The LM2676 is part of the ***SIMPLE SWITCHER*** family of power converters. A complete design uses a minimum number of external components, which have been pre-determined from a variety of manufacturers. Using either this data sheet or a design software program called ***LM267X Made Simple*** (version 2.0) a complete switching power supply can be designed quickly. The software is provided free of charge and can be downloaded from National Semiconductor's Internet site located at http://www.national.com.

SWITCH OUTPUT

This is the output of a power MOSFET switch connected directly to the input voltage. The switch provides energy to an inductor, an output capacitor and the load circuitry under control of an internal pulse-width-modulator (PWM). The PWM controller is internally clocked by a fixed 260KHz oscillator. In a standard step-down application the duty cycle (Time ON/ Time OFF) of the power switch is proportional to the ratio of the power supply output voltage to the input voltage. The voltage on pin 1 switches between Vin (switch ON) and below ground by the voltage drop of the external Schottky diode (switch OFF).

INPUT

The input voltage for the power supply is connected to pin 2. In addition to providing energy to the load the input voltage also provides bias for the internal circuitry of the LM2676. For guaranteed performance the input voltage must be in the range of 8V to 40V. For best performance of the power supply the input pin should always be bypassed with an input capacitor located close to pin 2.

C BOOST

A capacitor must be connected from pin 3 to the switch output, pin 1. This capacitor boosts the gate drive to the internal MOSFET above Vin to fully turn it ON. This minimizes conduction losses in the power switch to maintain high efficiency. The recommended value for C Boost is 0.01µF.

GROUND

This is the ground reference connection for all components in the power supply. In fast-switching, high-current applications such as those implemented with the LM2676, it is recommended that a broad ground plane be used to minimize signal coupling throughout the circuit

FEEDBACK

This is the input to a two-stage high gain amplifier, which drives the PWM controller. It is necessary to connect pin 6 to the actual output of the power supply to set the dc output voltage. For the fixed output devices (3.3V, 5V and 12V outputs), a direct wire connection to the output is all that is required as internal gain setting resistors are provided inside the LM2676. For the adjustable output version two external resistors are required to set the dc output voltage. For stable operation of the power supply it is important to prevent coupling of any inductor flux to the feedback input.

ON/OFF

This input provides an electrical ON/OFF control of the power supply. Connecting this pin to ground or to any voltage less than 0.8V will completely turn OFF the regulator. The current drain from the input supply when OFF is only 50µA. Pin 7 has an internal pull-up current source of approximately 20µA and a protection clamp zener diode of 7V to ground. When electrically driving the ON/OFF pin the high voltage level for the ON condition should not exceed the 6V absolute maximum limit. When ON/OFF control is not required pin 7 should be left open circuited.

DAP (LLP PACKAGE)

The Die Attach Pad (DAP) can and should be connected to PCB Ground plane/island. For CAD and assembly guidelines refer to Application Note AN-1187 at http://power.national.com.

DESIGN CONSIDERATIONS

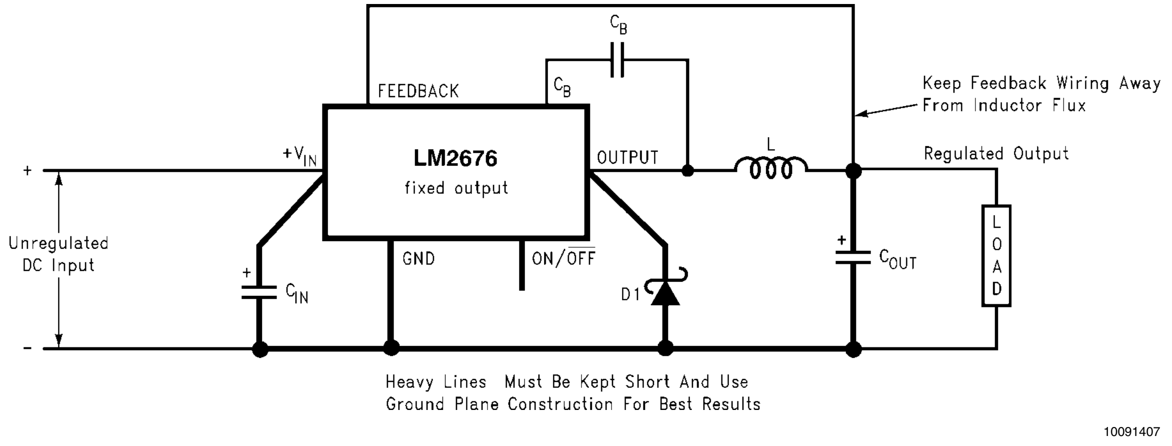


FIGURE 1. Basic circuit for fixed output voltage applications.

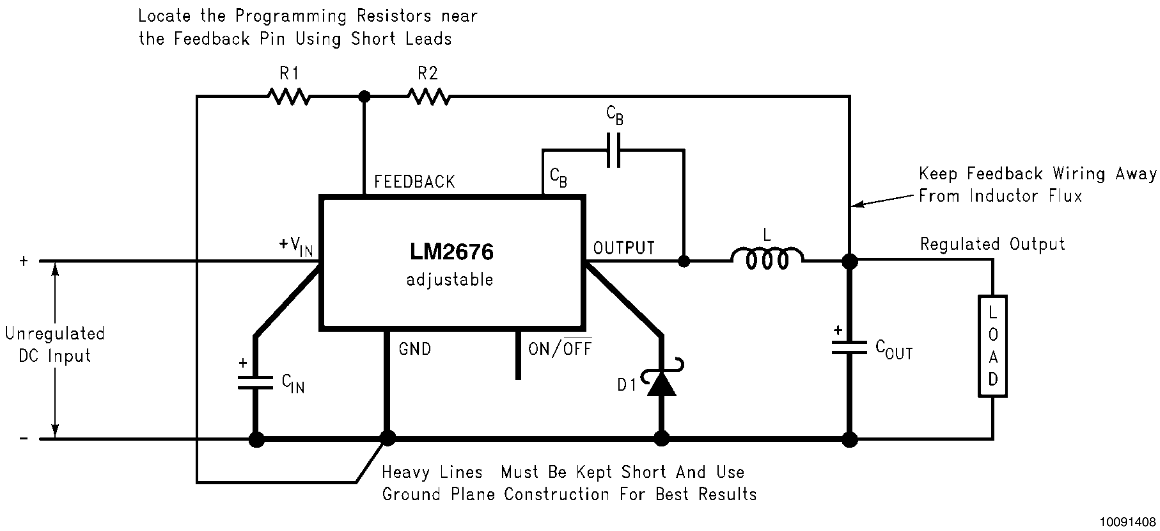


FIGURE 2. Basic circuit for adjustable output voltage applications

Power supply design using the LM2676 is greatly simplified by using recommended external components. A wide range of inductors, capacitors and Schottky diodes from several manufacturers have been evaluated for use in designs that cover the full range of capabilities (input voltage, output voltage and load current) of the LM2676. A simple design procedure using nomographs and component tables provided in this data sheet leads to a working design with very little effort. Alternatively, the design software, ***LM267X Made Simple*** (version 6.0), can also be used to provide instant component selection, circuit performance calculations for evaluation, a bill of materials component list and a circuit schematic.

The individual components from the various manufacturers called out for use are still just a small sample of the vast array of components available in the industry. While these components are recommended, they are not exclusively the only components for use in a design. After a close comparison of component specifications, equivalent devices from other manufacturers could be substituted for use in an application.

Important considerations for each external component and an explanation of how the nomographs and selection tables were developed follows.

INDUCTOR

The inductor is the key component in a switching regulator. For efficiency the inductor stores energy during the switch ON time and then transfers energy to the load while the switch is OFF.

Nomographs are used to select the inductance value required for a given set of operating conditions. The nomographs assume that the circuit is operating in continuous mode (the current flowing through the inductor never falls to zero). The magnitude of inductance is selected to maintain a maximum ripple current of 30% of the maximum load current. If the ripple current exceeds this 30% limit the next larger value is selected.

The inductors offered have been specifically manufactured to provide proper operation under all operating conditions of input and output voltage and load current. Several part types are offered for a given amount of inductance. Both surface mount and through-hole devices are available. The inductors from each of the three manufacturers have unique characteristics.

Renco: ferrite stick core inductors; benefits are typically lowest cost and can withstand ripple and transient peak currents above the rated value. These inductors have an external magnetic field, which may generate EMI.

Pulse Engineering: powdered iron toroid core inductors; these also can withstand higher than rated currents and, being toroid inductors, will have low EMI.

Coilcraft: ferrite drum core inductors; these are the smallest physical size inductors and are available only as surface mount components. These inductors also generate EMI but less than stick inductors.

OUTPUT CAPACITOR

The output capacitor acts to smooth the dc output voltage and also provides energy storage. Selection of an output capacitor, with an associated equivalent series resistance (ESR), impacts both the amount of output ripple voltage and stability of the control loop.

The output ripple voltage of the power supply is the product of the capacitor ESR and the inductor ripple current. The capacitor types recommended in the tables were selected for having low ESR ratings.

In addition, both surface mount tantalum capacitors and through-hole aluminum electrolytic capacitors are offered as solutions.

Impacting frequency stability of the overall control loop, the output capacitance, in conjunction with the inductor, creates a double pole inside the feedback loop. In addition the capacitance and the ESR value create a zero. These frequency response effects together with the internal frequency compensation circuitry of the LM2676 modify the gain and phase shift of the closed loop system.

As a general rule for stable switching regulator circuits it is desired to have the unity gain bandwidth of the circuit to be limited to no more than one-sixth of the controller switching frequency. With the fixed 260KHz switching frequency of the LM2676, the output capacitor is selected to provide a unity gain bandwidth of 40KHz maximum. Each recommended capacitor value has been chosen to achieve this result.

In some cases multiple capacitors are required either to reduce the ESR of the output capacitor, to minimize output ripple (a ripple voltage of 1% of Vout or less is the assumed performance condition), or to increase the output capacitance to reduce the closed loop unity gain bandwidth (to less than 40KHz). When parallel combinations of capacitors are required it has been assumed that each capacitor is the exact same part type.

The RMS current and working voltage (WV) ratings of the output capacitor are also important considerations. In a typical step-down switching regulator, the inductor ripple current (set to be no more than 30% of the maximum load current by the inductor selection) is the current that flows through the output capacitor. The capacitor RMS current rating must be greater than this ripple current. The voltage rating of the output capacitor should be greater than 1.3 times the maximum output voltage of the power supply. If operation of the system at elevated temperatures is required, the capacitor voltage rating may be de-rated to less than the nominal room temperature rating. Careful inspection of the manufacturer's specification for de-rating of working voltage with temperature is important.

INPUT CAPACITOR

Fast changing currents in high current switching regulators place a significant dynamic load on the unregulated power source. An input capacitor helps to provide additional current to the power supply as well as smooth out input voltage variations.

Like the output capacitor, the key specifications for the input capacitor are RMS current rating and working voltage. The RMS current flowing through the input capacitor is equal to one-half of the maximum dc load current so the capacitor should be rated to handle this. Paralleling multiple capacitors proportionally increases the current rating of the total capacitance. The voltage rating should also be selected to be 1.3 times the maximum input voltage. Depending on the unregulated input power source, under light load conditions the maximum input voltage could be significantly higher than normal operation and should be considered when selecting an input capacitor.

The input capacitor should be placed very close to the input pin of the LM2676. Due to relative high current operation with fast transient changes, the series inductance of input connecting wires or PCB traces can create ringing signals at the input terminal which could possibly propagate to the output or other parts of the circuitry. It may be necessary in some designs to add a small valued (0.1µF to 0.47µF) ceramic type capacitor in parallel with the input capacitor to prevent or minimize any ringing.

CATCH DIODE

When the power switch in the LM2676 turns OFF, the current through the inductor continues to flow. The path for this current is through the diode connected between the switch output and ground. This forward biased diode clamps the switch output to a voltage less than ground. This negative voltage must be greater than −1V so a low voltage drop (particularly at high current levels) Schottky diode is recommended. Total efficiency of the entire power supply is significantly impacted by the power lost in the output catch diode. The average current through the catch diode is dependent on the switch duty cycle (D) and is equal to the load current times (1-D). Use of a diode rated for much higher current than is required by the actual application helps to minimize the voltage drop and power loss in the diode.

During the switch ON time the diode will be reversed biased by the input voltage. The reverse voltage rating of the diode should be at least 1.3 times greater than the maximum input voltage.

BOOST CAPACITOR

The boost capacitor creates a voltage used to overdrive the gate of the internal power MOSFET. This improves efficiency by minimizing the on resistance of the switch and associated power loss. For all applications it is recommended to use a 0.01µF/50V ceramic capacitor.

ADDITIONAL APPLICATON INFORMATION

When the output voltage is greater than approximately 6V, and the duty cycle at minimum input voltage is greater than approximately 50%, the designer should exercise caution in selection of the output filter components. When an application designed to these specific operating conditions is subjected to a current limit fault condition, it may be possible to observe a large hysteresis in the current limit. This can affect the output voltage of the device until the load current is reduced sufficiently to allow the current limit protection circuit to reset itself.

Under current limiting conditions, the LM267x is designed to respond in the following manner:

1. At the moment when the inductor current reaches the current limit threshold, the ON-pulse is immediately terminated. This happens for any application condition.
2. However, the current limit block is also designed to momentarily reduce the duty cycle to below 50% to avoid subharmonic oscillations, which could cause the inductor to saturate.
3. Thereafter, once the inductor current falls below the current limit threshold, there is a small relaxation time during which the duty cycle progressively rises back above 50% to the value required to achieve regulation.

If the output capacitance is sufficiently 'large', it may be possible that as the output tries to recover, the output capacitor charging current is large enough to repeatedly re-trigger the current limit circuit before the output has fully settled. This condition is exacerbated with higher output voltage settings because the energy requirement of the output capacitor varies as the square of the output voltage ($\frac{1}{2}CV^2$), thus requiring an increased charging current.

A simple test to determine if this condition might exist for a suspect application is to apply a short circuit across the output of the converter, and then remove the shorted output condition. In an application with properly selected external components, the output will recover smoothly.

Practical values of external components that have been experimentally found to work well under these specific operating conditions are C_{OUT} = 47µF, L = 22µH. It should be noted that even with these components, for a device's current limit of I_{CLIM}, the maximum load current under which the possibility of the large current limit hysteresis can be minimized is $I_{CLIM}/2$. For example, if the input is 24V and the set output voltage is 18V, then for a desired maximum current of 1.5A, the current limit of the chosen switcher must be confirmed to be at least 3A.

Under extreme over-current or short circuit conditions, the LM267X employs frequency foldback in addition to the current limit. If the cycle-by-cycle inductor current increases above the current limit threshold (due to short circuit or inductor saturation for example) the switching frequency will be automatically reduced to protect the IC. Frequency below 100 KHz is typical for an extreme short circuit condition.

SIMPLE DESIGN PROCEDURE

Using the nomographs and tables in this data sheet (or use the available design software at http://www.national.com) a complete step-down regulator can be designed in a few simple steps.

Step 1: Define the power supply operating conditions:

Required output voltage

Maximum DC input voltage

Maximum output load current

Step 2: Set the output voltage by selecting a fixed output LM2676 (3.3V, 5V or 12V applications) or determine the required feedback resistors for use with the adjustable LM2676 –ADJ

Step 3: Determine the inductor required by using one of the four nomographs, *Figure 3* through *Figure 6*. Table 1 provides a specific manufacturer and part number for the inductor.

Step 4: Using Table 3 (fixed output voltage) or Table 6 (adjustable output voltage), determine the output capacitance required for stable operation. Table 2 provides the specific capacitor type from the manufacturer of choice.

Step 5: Determine an input capacitor from Table 4 for fixed output voltage applications. Use Table 2 to find the specific capacitor type. For adjustable output circuits select a capacitor from Table 2 with a sufficient working voltage (WV) rating greater than Vin max, and an rms current rating greater than one-half the maximum load current (2 or more capacitors in parallel may be required).

Step 6: Select a diode from Table 5. The current rating of the diode must be greater than I load max and the Reverse Voltage rating must be greater than Vin max.

Step 7: Include a 0.01µF/50V capacitor for Cboost in the design.

FIXED OUTPUT VOLTAGE DESIGN EXAMPLE

A system logic power supply bus of 3.3V is to be generated from a wall adapter which provides an unregulated DC voltage of 13V to 16V. The maximum load current is 2.5A. Through-hole components are preferred.

Step 1: Operating conditions are:

Vout = 3.3V

Vin max = 16V

Iload max = 2.5A

Step 2: Select an LM2676T-3.3. The output voltage will have a tolerance of

±2% at room temperature and ±3% over the full operating temperature range.

Step 3: Use the nomograph for the 3.3V device ,*Figure 3*. The intersection of the 16V horizontal line (V_{in} max) and the 2.5A vertical line (I_{load} max) indicates that L33, a 22µH inductor, is required.

From Table 1, L33 in a through-hole component is available from Renco with part number RL-1283-22-43 or part number PE-53933 from Pulse Engineering.

Step 4: Use Table 3 to determine an output capacitor. With a 3.3V output and a 22µH inductor there are four through-hole output capacitor solutions with the number of same type capacitors to be paralleled and an identifying capacitor code given. Table 2 provides the actual capacitor characteristics. Any of the following choices will work in the circuit:

1 x 220µF/10V Sanyo OS-CON (code C5)

1 x 1000µF/35V Sanyo MV-GX (code C10)

1 x 2200µF/10V Nichicon PL (code C5)

1 x 1000µF/35V Panasonic HFQ (code C7)

Step 5: Use Table 4 to select an input capacitor. With 3.3V output and 22µH there are three through-hole solutions. These capacitors provide a sufficient voltage rating and an rms current rating greater than 1.25A (1/2 I_{load} max). Again using Table 2 for specific component characteristics the following choices are suitable:

1 x 1000µF/63V Sanyo MV-GX (code C14)

1 x 820µF/63V Nichicon PL (code C24)

1 x 560µF/50V Panasonic HFQ (code C13)

Step 6: From Table 5 a 3A Schottky diode must be selected. For through-hole components 20V rated diodes are sufficient and 2 part types are suitable:

1N5820

SR302

Step 7: A 0.01µF capacitor will be used for Cboost.

ADJUSTABLE OUTPUT DESIGN EXAMPLE

In this example it is desired to convert the voltage from a two battery automotive power supply (voltage range of 20V to 28V, typical in large truck applications) to the 14.8VDC alternator supply typically used to power electronic equipment from single battery 12V vehicle systems. The load current required is 2A maximum. It is also desired to implement the power supply with all surface mount components.

Step 1: Operating conditions are:

Vout = 14.8V

Vin max = 28V

Iload max = 2A

Step 2: Select an LM2676S-ADJ. To set the output voltage to 14.9V two resistors need to be chosen (R1 and R2 in *Figure 2*). For the adjustable device the output voltage is set by the following relationship:

$$V_{OUT} = V_{FB}\left(1 + \frac{R_2}{R_1}\right)$$

Where V_{FB} is the feedback voltage of typically 1.21V.

A recommended value to use for R1 is 1K. In this example then R2 is determined to be:

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{FB}} - 1\right) = 1\,k\Omega\left(\frac{14.8V}{1.21V} - 1\right)$$

R2 = 11.23KΩ

The closest standard 1% tolerance value to use is 11.3KΩ

This will set the nominal output voltage to 14.88V which is within 0.5% of the target value.

Step 3: To use the nomograph for the adjustable device, *Figure 6*, requires a calculation of the inductor Volt•microsecond constant (E•T expressed in V•µS) from the following formula:

$$E \cdot T = (V_{IN(MAX)} - V_{OUT} - V_{SAT}) \cdot \frac{V_{OUT} + V_D}{V_{IN(MAX)} - V_{SAT} + V_D} \cdot \frac{1000}{260}\ (V \cdot \mu s)$$

where V_{SAT} is the voltage drop across the internal power switch which is $R_{ds(ON)}$ times I_{load}. In this example this would be typically 0.15Ω x 2A or 0.3V and V_D is the voltage drop across the forward bisased Schottky diode, typically 0.5V. The switching frequency of 260KHz is the nominal value to use to estimate the ON time of the switch during which energy is stored in the inductor.

For this example E•T is found to be:

$$E \cdot T = (28 - 14.8 - 0.3) \cdot \frac{14.8 + 0.5}{28 - 0.3 + 0.5} \cdot \frac{1000}{260} \ (V \cdot \mu s)$$

$$E \cdot T = (12.9V) \cdot \frac{15.3}{28.2} \cdot 3.85 \ (V \cdot \mu s) = 26.9 \ (V \cdot \mu s)$$

Using *Figure 6*, the intersection of 27V•µS horizontally and the 2A vertical line (I_{load} max) indicates that L38 , a 68µH inductor, should be used.

From Table 1, L38 in a surface mount component is available from Pulse Engineering with part number PE-54038S.

Step 4: Use Table 6 to determine an output capacitor. With a 14.8V output the 12.5 to 15V row is used and with a 68µH inductor there are three surface mount output capacitor solutions. Table 2 provides the actual capacitor characteristics based on the C Code number. Any of the following choices can be used:

1 x 33µF/20V AVX TPS (code C6)

1 x 47µF/20V Sprague 594 (code C8)

1 x 47µF/20V Kemet T495 (code C8)

Important Note: When using the adjustable device in low voltage applications (less than 3V output), if the nomograph, Figure 6, selects an inductance of 22µH or less, Table 6 does not provide an output capacitor solution. With these conditions the number of output capacitors required for stable operation becomes impractical. It is recommended to use either a 33µH or 47µH inductor and the output capacitors from Table 6.

Step 5: An input capacitor for this example will require at least a 35V WV rating with an rms current rating of 1A (1/2 Iout max). From Table 2 it can be seen that C12, a 33µF/35V capacitor from Sprague, has the required voltage/current rating of the surface mount components.

Step 6: From Table 5 a 3A Schottky diode must be selected. For surface mount diodes with a margin of safety on the voltage rating one of five diodes can be used:

SK34

30BQ040

30WQ04F

MBRS340

MBRD340

Step 7: A 0.01µF capacitor will be used for Cboost.

LLP PACKAGE DEVICES

The LM2676 is offered in the 14 lead LLP surface mount package to allow for a significantly decreased footprint with equivalent power dissipation compared to the TO-263. For details on mounting and soldering specifications, refer to Application Note AN-1187.

Inductor Selection Guides

For Continuous Mode Operation

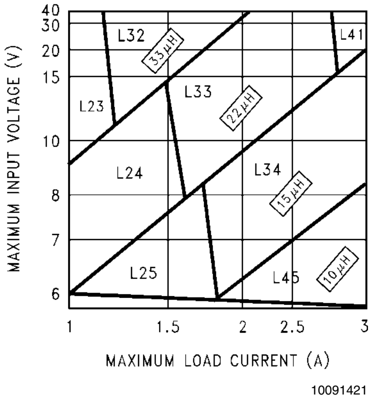


FIGURE 3. LM2676-3.3

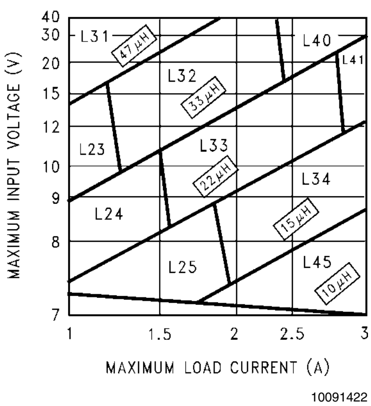


FIGURE 4. LM2676-5.0

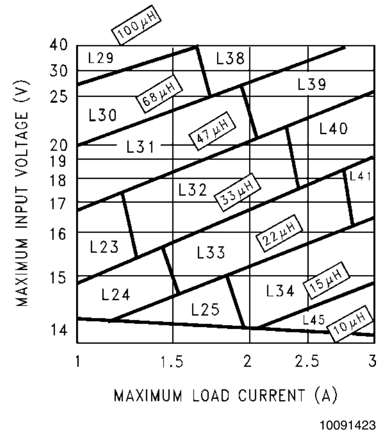


FIGURE 5. LM2676-12

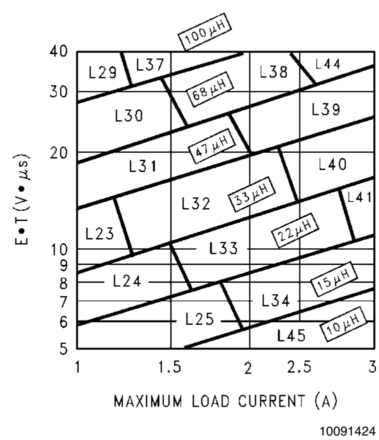


FIGURE 6. LM2676-ADJ

Table 1. Inductor Manufacturer Part Numbers

Inductor Reference Number	Inductance (µH)	Current (A)	Renco		Pulse Engineering		Coilcraft
			Through Hole	Surface Mount	Through Hole	Surface Mount	Surface Mount
L23	33	1.35	RL-5471-7	RL1500-33	PE-53823	PE-53823S	DO3316-333
L24	22	1.65	RL-1283-22-43	RL1500-22	PE-53824	PE-53824S	DO3316-223
L25	15	2.00	RL-1283-15-43	RL1500-15	PE-53825	PE-53825S	DO3316-153
L29	100	1.41	RL-5471-4	RL-6050-100	PE-53829	PE-53829S	DO5022P-104
L30	68	1.71	RL-5471-5	RL6050-68	PE-53830	PE-53830S	DO5022P-683
L31	47	2.06	RL-5471-6	RL6050-47	PE-53831	PE-53831S	DO5022P-473
L32	33	2.46	RL-5471-7	RL6050-33	PE-53932	PE-53932S	DO5022P-333
L33	22	3.02	RL-1283-22-43	RL6050-22	PE-53933	PE-53933S	DO5022P-223
L34	15	3.65	RL-1283-15-43	—	PE-53934	PE-53934S	DO5022P-153
L38	68	2.97	RL-5472-2	—	PE-54038	PE-54038S	—
L39	47	3.57	RL-5472-3	—	PE-54039	PE-54039S	—
L40	33	4.26	RL-1283-33-43	—	PE-54040	PE-54040S	—
L41	22	5.22	RL-1283-22-43	—	PE-54041	P0841	—
L44	68	3.45	RL-5473-3	—	PE-54044	—	—
L45	10	4.47	RL-1283-10-43	—	—	P0845	DO5022P-103HC

Inductor Manufacturer Contact Numbers

Coilcraft	Phone	(800) 322-2645
	FAX	(708) 639-1469
Coilcraft, Europe	Phone	+44 1236 730 595
	FAX	+44 1236 730 627
Pulse Engineering	Phone	(619) 674-8100
	FAX	(619) 674-8262
Pulse Engineering, Europe	Phone	+353 93 24 107
	FAX	+353 93 24 459
Renco Electronics	Phone	(800) 645-5828
	FAX	(516) 586-5562

Capacitor Selection Guides

Table 2. Input and Output Capacitor Codes

Capacitor Reference Code	Surface Mount								
	AVX TPS Series			Sprague 594D Series			Kemet T495 Series		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	330	6.3	1.15	120	6.3	1.1	100	6.3	0.82
C2	100	10	1.1	220	6.3	1.4	220	6.3	1.1
C3	220	10	1.15	68	10	1.05	330	6.3	1.1
C4	47	16	0.89	150	10	1.35	100	10	1.1
C5	100	16	1.15	47	16	1	150	10	1.1
C6	33	20	0.77	100	16	1.3	220	10	1.1
C7	68	20	0.94	180	16	1.95	33	20	0.78
C8	22	25	0.77	47	20	1.15	47	20	0.94
C9	10	35	0.63	33	25	1.05	68	20	0.94
C10	22	35	0.66	68	25	1.6	10	35	0.63
C11				15	35	0.75	22	35	0.63
C12				33	35	1	4.7	50	0.66
C13				15	50	0.9			

Input and Output Capacitor Codes (continued)

Capacitor Reference Code	Through Hole											
	Sanyo OS-CON SA Series			Sanyo MV-GX Series			Nichicon PL Series			Panasonic HFQ Series		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	47	6.3	1	1000	6.3	0.8	680	10	0.8	82	35	0.4
C2	150	6.3	1.95	270	16	0.6	820	10	0.98	120	35	0.44
C3	330	6.3	2.45	470	16	0.75	1000	10	1.06	220	35	0.76
C4	100	10	1.87	560	16	0.95	1200	10	1.28	330	35	1.01
C5	220	10	2.36	820	16	1.25	2200	10	1.71	560	35	1.4
C6	33	16	0.96	1000	16	1.3	3300	10	2.18	820	35	1.62
C7	100	16	1.92	150	35	0.65	3900	10	2.36	1000	35	1.73
C8	150	16	2.28	470	35	1.3	6800	10	2.68	2200	35	2.8
C9	100	20	2.25	680	35	1.4	180	16	0.41	56	50	0.36
C10	47	25	2.09	1000	35	1.7	270	16	0.55	100	50	0.5
C11				220	63	0.76	470	16	0.77	220	50	0.92
C12				470	63	1.2	680	16	1.02	470	50	1.44
C13				680	63	1.5	820	16	1.22	560	50	1.68
C14				1000	63	1.75	1800	16	1.88	1200	50	2.22
C15							220	25	0.63	330	63	1.42
C16							220	35	0.79	1500	63	2.51
C17							560	35	1.43			
C18							2200	35	2.68			
C19							150	50	0.82			
C20							220	50	1.04			
C21							330	50	1.3			
C22							100	63	0.75			
C23							390	63	1.62			
C24							820	63	2.22			
C25							1200	63	2.51			

Capacitor Manufacturer Contact Numbers

Nichicon	Phone	(847) 843-7500
	FAX	(847) 843-2798
Panasonic	Phone	(714) 373-7857
	FAX	(714) 373-7102
AVX	Phone	(845) 448-9411
	FAX	(845) 448-1943
Sprague/Vishay	Phone	(207) 324-4140
	FAX	(207) 324-7223
Sanyo	Phone	(619) 661-6322
	FAX	(619) 661-1055
Kemet	Phone	(864) 963-6300
	FAX	(864) 963-6521

Table 3. Output Capacitors for Fixed Output Voltage Application

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.3	10	4	C2	3	C1	4	C4
	15	4	C2	3	C1	4	C4
	22	3	C2	2	C7	3	C4
	33	2	C2	2	C6	2	C4
5	10	4	C2	4	C6	4	C4
	15	3	C2	2	C7	3	C4
	22	3	C2	2	C7	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	1	C7	2	C4
12	10	4	C5	3	C6	5	C9
	15	3	C5	2	C7	4	C8
	22	2	C5	2	C6	3	C8
	33	2	C5	1	C7	2	C8
	47	2	C4	1	C6	2	C8
	68	1	C5	1	C5	2	C7
	100	1	C4	1	C5	1	C8

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.3	10	1	C3	1	C10	1	C6	2	C6
	15	1	C3	1	C10	1	C6	2	C5
	22	1	C5	1	C10	1	C5	1	C7
	33	1	C2	1	C10	1	C13	1	C5
5	10	2	C4	1	C10	1	C6	2	C5
	15	1	C5	1	C10	1	C5	1	C6
	22	1	C5	1	C5	1	C5	1	C5
	33	1	C4	1	C5	1	C13	1	C5
	47	1	C4	1	C4	1	C13	2	C3

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
12	10	2	C7	1	C5	1	C18	2	C5
	15	1	C8	1	C5	1	C17	1	C5
	22	1	C7	1	C5	1	C13	1	C5
	33	1	C7	1	C3	1	C11	1	C4
	47	1	C7	1	C3	1	C10	1	C3
	68	1	C7	1	C2	1	C10	1	C3
	100	1	C7	1	C2	1	C9	1	C1

No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in Table 2 for identifying the specific component from the manufacturer.

Table 4. Input Capacitors for Fixed Output Voltage Application

(Assumes worst case maximum input voltage and load current for a given inductance value)

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.3	10	2	C5	1	C7	2	C8
	15	3	C9	1	C10	3	C10
	22	*	*	2	C13	3	C12
	33	*	*	2	C13	2	C12
5	10	2	C5	1	C7	2	C8
	15	2	C5	1	C7	2	C8
	22	3	C10	2	C12	3	C11
	33	*	*	2	C13	3	C12
	47	*	*	1	C13	2	C12
12	10	2	C7	2	C10	2	C7
	15	2	C7	2	C10	2	C7
	22	3	C10	2	C12	3	C10
	33	3	C10	2	C12	3	C10
	47	*	*	2	C13	3	C12
	68	*	*	2	C13	2	C12
	100	*	*	1	C13	2	C12

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.3	10	1	C7	2	C4	1	C5	1	C6
	15	1	C10	1	C10	1	C18	1	C6
	22	*	*	1	C14	1	C24	1	C13
	33	*	*	1	C12	1	C20	1	C12
5	10	1	C7	2	C4	1	C14	1	C6
	15	1	C7	2	C4	1	C14	1	C6
	22	*	*	1	C10	1	C18	1	C13
	33	*	*	1	C14	1	C23	1	C13
	47	*	*	1	C12	1	C20	1	C12

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
12	10	1	C9	1	C10	1	C18	1	C6
	15	1	C10	1	C10	1	C18	1	C6
	22	1	C10	1	C10	1	C18	1	C6
	33	*	*	1	C10	1	C18	1	C6
	47	*	*	1	C13	1	C23	1	C13
	68	*	*	1	C12	1	C21	1	C12
	100	*	*	1	C11	1	C22	1	C11

* Check voltage rating of capacitors to be greater than application input voltage.
No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in Table 2 for identifying the specific component from the manufacturer.

Table 5. Schottky Diode Selection Table

Reverse Voltage (V)	Surface Mount		Through Hole	
	3A	5A or More	3A	5A or More
20V	SK32		1N5820 SR302	
30V	SK33 30WQ03F	MBRD835L	1N5821 31DQ03	
40V	SK34 30BQ040 30WQ04F MBRS340 MBRD340	MBRB1545CT 6TQ045S	1N5822 MBR340 31DQ04 SR403	MBR745 80SQ045 6TQ045
50V or More	SK35 30WQ05F		MBR350 31DQ05 SR305	

Diode Manufacturer Contact Numbers

International Rectifier	Phone	(310) 322-3331
	FAX	(310) 322-3332
Motorola	Phone	(800) 521-6274
	FAX	(602) 244-6609
General Semiconductor	Phone	(516) 847-3000
	FAX	(516) 847-3236
Diodes, Inc.	Phone	(805) 446-4800
	FAX	(805) 446-4850

Table 6. Output Capacitors for Adjustable Output Voltage Applications

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
1.21 to 2.50	33*	7	C1	6	C2	7	C3
	47*	5	C1	4	C2	5	C3
2.5 to 3.75	33*	4	C1	3	C2	4	C3
	47*	3	C1	2	C2	3	C3

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.75 to 5	22	4	C1	3	C2	4	C3
	33	3	C1	2	C2	3	C3
	47	2	C1	2	C2	2	C3
5 to 6.25	22	3	C2	3	C3	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	2	C3	2	C4
	68	1	C2	1	C3	1	C4
6.25 to 7.5	22	3	C2	1	C4	3	C4
	33	2	C2	1	C3	2	C4
	47	1	C3	1	C4	1	C6
	68	1	C2	1	C3	1	C4
7.5 to 10	33	2	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C4	1	C5	1	C8
10 to 12.5	33	1	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C5	1	C6	1	C8
12.5 to 15	33	1	C6	1	C8	1	C8
	47	1	C6	1	C8	1	C8
	68	1	C6	1	C8	1	C8
	100	1	C6	1	C8	1	C8
15 to 20	33	1	C8	1	C10	2	C10
	47	1	C8	1	C9	2	C10
	68	1	C8	1	C9	2	C10
	100	1	C8	1	C9	1	C10
20 to 30	33	2	C9	2	C11	2	C11
	47	1	C10	1	C12	1	C11
	68	1	C9	1	C12	1	C11
	100	1	C9	1	C12	1	C11
30 to 37	10	No Values Available		4	C13	8	C12
	15			3	C13	5	C12
	22			2	C13	4	C12
	33			1	C13	3	C12
	47			1	C13	2	C12
	68			1	C13	2	C12

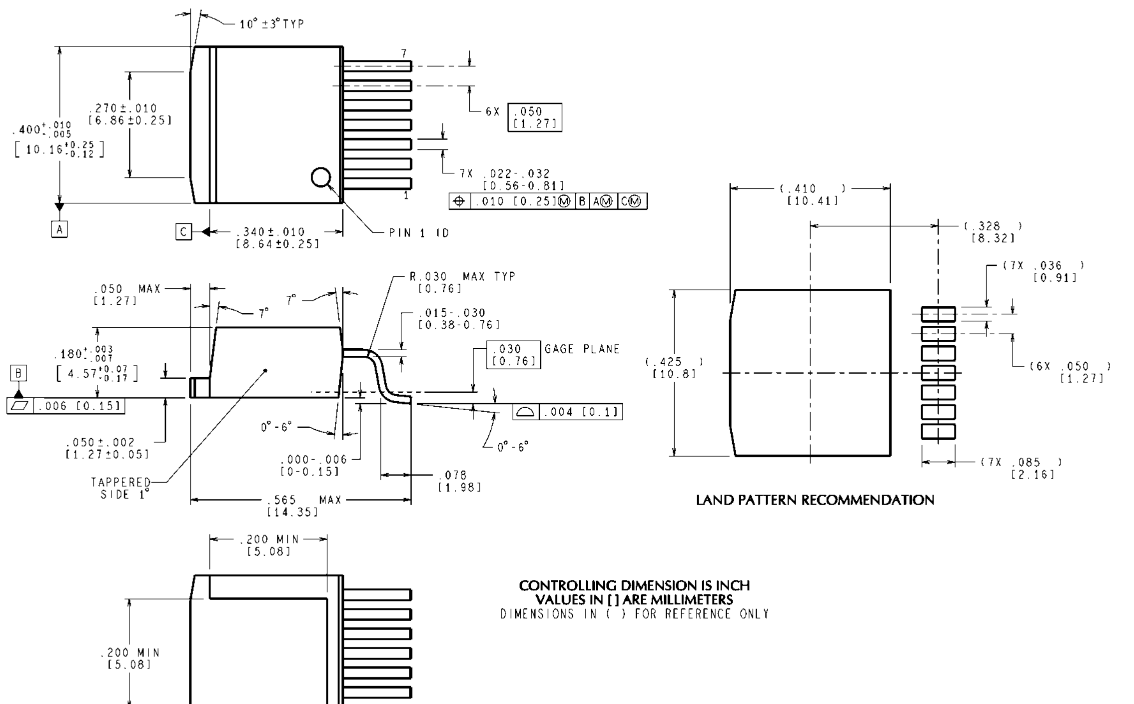
Output Capacitors for Adjustable Output Voltage Applications (continued)

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
1.21 to 2.50	33*	2	C3	5	C1	5	C3	3	C
	47*	2	C2	4	C1	3	C3	2	C5
2.5 to 3.75	33*	1	C3	3	C1	3	C1	2	C5
	47*	1	C2	2	C1	2	C3	1	C5

Output Voltage (V)	Inductance (µH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.75 to 5	22	1	C3	3	C1	3	C1	2	C5
	33	1	C2	2	C1	2	C1	1	C5
	47	1	C2	2	C1	1	C3	1	C5
5 to 6.25	22	1	C5	2	C6	2	C3	2	C5
	33	1	C4	1	C6	2	C1	1	C5
	47	1	C4	1	C6	1	C3	1	C5
	68	1	C4	1	C6	1	C1	1	C5
6.25 to 7.5	22	1	C5	1	C6	2	C1	1	C5
	33	1	C4	1	C6	1	C3	1	C5
	47	1	C4	1	C6	1	C1	1	C5
	68	1	C4	1	C2	1	C1	1	C5
7.5 to 10	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C6	1	C14	1	C5
	68	1	C7	1	C2	1	C14	1	C2
	100	1	C7	1	C2	1	C14	1	C2
10 to 12.5	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C2	1	C14	1	C5
	68	1	C7	1	C2	1	C9	1	C2
	100	1	C7	1	C2	1	C9	1	C2
12.5 to 15	33	1	C9	1	C10	1	C15	1	C2
	47	1	C9	1	C10	1	C15	1	C2
	68	1	C9	1	C10	1	C15	1	C2
	100	1	C9	1	C10	1	C15	1	C2
15 to 20	33	1	C10	1	C7	1	C15	1	C2
	47	1	C10	1	C7	1	C15	1	C2
	68	1	C10	1	C7	1	C15	1	C2
	100	1	C10	1	C7	1	C15	1	C2
20 to 30	33	No Values Available		1	C7	1	C16	1	C2
	47			1	C7	1	C16	1	C2
	68			1	C7	1	C16	1	C2
	100			1	C7	1	C16	1	C2
30 to 37	10	No Values Available		1	C12	1	C20	1	C10
	15			1	C11	1	C20	1	C11
	22			1	C11	1	C20	1	C10
	33			1	C11	1	C20	1	C10
	47			1	C11	1	C20	1	C10
	68			1	C11	1	C20	1	C10

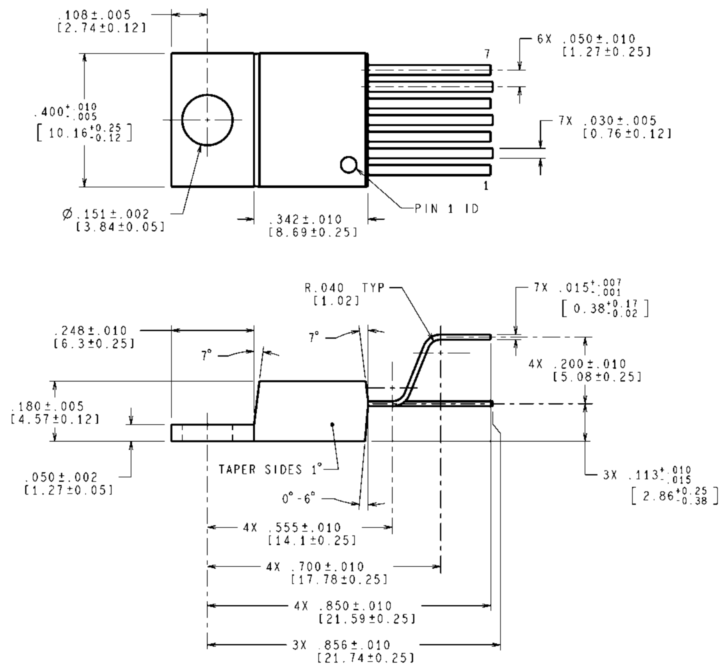
* Set to a higher value for a practical design solution. See Applications Hints section
No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in Table 2 for identifying the specific component from the manufacturer.

Physical Dimensions inches (millimeters) unless otherwise noted



TS7B (Rev E)

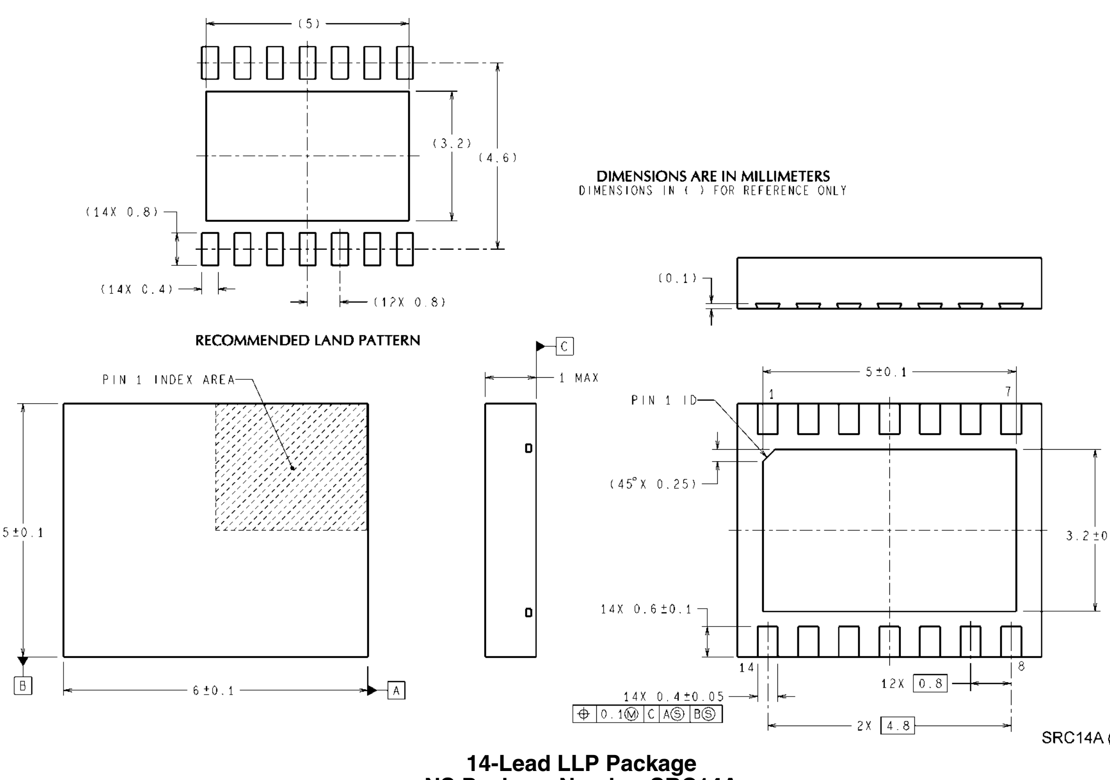
TO-263 Surface Mount Power Package
Order Number LM2676S-3.3, LM2676S-5.0,
LM2676S-12 or LM2676S-ADJ
NS Package Number TS7B



CONTROLING DIMENSIONS IS INCH
VALUES IN [ ] ARE MILLIMETERS

TA07B (Rev E)

TO-220 Power Package
Order Number LM2676T-3.3, LM2676T-5.0,
LM2676T-12 or LM2676T-ADJ
NS Package Number TA07B



SRC14A (Rev A)

14-Lead LLP Package
NS Package Number SRC14A

Notes

Notes

IMPORTANT NOTICE

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

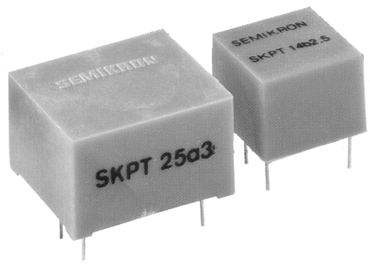
Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
		TI E2E Community Home Page	e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

back zurück

14.2 Pulse Transformers
Range of preferred types

Pulse Transformers
SKPT 14 to SKPT 27



Absolute Maximum Ratings		
Symbol	**Conditions**	**Values**
V_{ww}	Crest working voltage	400 ... 650 V
V_{isol}	A.C. rms; 1 minute, see table below [1]	2,5 ... 5 kV
T_{op}	Operating Temperature	– 40 ... + 85 °C
T_{stg}	Storage Temperature	– 50 ... + 90 °C

Characteristics [2]

Types • New Type	N_p/N_s s	$\int V dt$ µVs	R_p Ω	R_s Ω	L_p mH	L_{ss} µH	C_{ps} pF	I_M mA	t_r µs	R_L Ω	V_{ww} V	V_{isol} kV	Win-ding conf
SKPT 14b2,5	1:1:1	250	0,86	0,86	1,8	85	10	150	2	80	500	4	B
SKPT 14k2,5	1:1:1	250	0,86	0,86	1,8	85	10	150	2	80	500	4	C
SKPT 14c2,5	2:1	250	1,6	0,86	7,5	400	12	150	2,5	80	500	4	D
SKPT 14a3	1:1	350	1,25	1,25	2,8	135	12	150	2,5	80	500	4	A
SKPT 14i3	1:1	350	1,25	1,25	2,8	135	12	150	2,5	80	500	4	D
SKPT 14g3	2:1:1	330	3,5	1,6	11	148	10	150	5	80	500	4	B
SKPT 14c3,5	2:1	350	3,5	2,4	13,5	82	9	150	2,5	80	500	4	D
SKPT 14i5	1:1	500	2,7	2,7	5,5	75	10	150	2,5	80	500	4	D
SKPT 14k6	1:1:1	600	2,8	2,8	9	290	10	150	2,5	80	500	4	C
SKPT 25j2	1:2:2	200	0,8	1,6	0,9/1,6	30/60	7	250	1,5	47	500	5	H
SKPT 25a3	1:1	300	0,55	0,55	2	45	8	250	1,5	47	500	4	A
SKPT 25b3	1:1:1	300	0,55	0,55	2	48	9	250	1,5	47	500	4	B
SKPT 25e3	3:1:1	300	1,7	0,55	15	300	10	250	1,5	47	500	4	B
SKPT 25h3	1:1:1:1	300	0,55	0,55	2	48	9	250	1,5	47	500	4	C
SKPT 25k3/650	1:1:1	300	0,55	0,55	2	38	9	250	1,5	47	650	4	F
SKPT 25m3	1:1	300	0,55	0,55	1,8	105	7	250	1,5	47	1000	6	G
SKPT 25n3	3:1	300	1,7	0,55	15	870	7	250	1,5	47	1000	6	G
SKPT 25p3/650	3:1:1	300	1,7	0,55	15	300	10	250	1,5	47	650	4	F
SKPT 25a4	1:1	400	0,6	0,6	4	50	10	250	2	47	500	4	A
SKPT 25b4	1:1:1	400	0,6	0,6	4	52	10	250	2	47	500	4	B
SKPT 25g4	2:1:1	400	2,3	1,1	9/15	260/490	7	250	1,5	47	500	5	H
SKPT 25a5	1:1	500	1	1	5,5	85	11	100 250	1,1 3	100 47	500	4	A

continued on next page

[1] Material used is according to UL94-V0. Isolation test and pin distance according to IEC 60664-1(1992); (VDE 0110-1:1997-4)
[2] Explanations see Chapter A, Section 14.2

14.2 Pulse Transformers (continued)

Types • New Type	N_p/N_s s	$\int Vdt$ µVs	R_p Ω	R_s Ω	L_p mH	L_{ss} µH	C_{ps} pF	I_M mA	t_r µs	R_L Ω	V_{ww} V	V_{isol} kV	Win-ding conf
SKPT 25b5	1:1:1	500	1	1	5,5	89	12	100 250	1,1 3	100 47	500	4	B
SKPT 25m5	1:1	500	1	1	5,5	170	7	250	1,5	47	1000	6	G
SKPT 25o5	2:1	500	2,1	1	32	830	7,5	250	1,5	47	1000	5	G
SKPT 25b8	1:1:1	800	1,6	1,6	14	220	14	25 250	1 6	470 47	500	4	B
SKPT 25b10	1:1:1	1000	1,8	1,8	18	260	13	25 250	1 6	470 47	500	4	B
SKPT 26a3	1:1	300	0,55	0,55	2	45	8	250	1,5	47	500	4	A
SKPT 26b3	1:1:1	300	0,55	0,55	2	48	8	250	1,5	47	500	4	B
SKPT 26e3	3:1:1	300	1,7	0,55	15	300	10	250	1,5	47	500	4	B
SKPT 26b10	1:1:1	1000	1,8	1,8	18	260	15	25 250	1 6	470 47	500	4	B
SKPT 21a3	1:1	270	0,6	0,6	3,5	3,5	55	800	0,8	15	650	4	A
SKPT 21b3	1:1:1	270	0,6	0,6	3,5	3,5	55	800	0,8	15	440	2,5	B
SKPT 21b3/650	1:1:1	270	0,6	0,5/0,7	3,5	2,7/3,2	30	800	0,8	15	650	4	B
SKPT 21c3	2:1	275	1,0	0,6	6,5	10	50	800	0,8	15	650	4	A
SKPT 21d3	3:1	270	1,5	0,6	30	20	65	800	0,8	15	650	4	A
SKPT 21e3	3:1:1	270	1,5	0,6	30	20	65	800	0,8	15	440	2,5	B
SKPT 21b4	1:1:1	370	0,7	0,7	6	3,5	65	800	0,8	15	440	2,5	B
SKPT 21b4/650	1:1:1	370	0,7	0,6/0,8	6	4,3/7	65	800	0,8	15	650	4	B
SKPT 21a5	1:1	450	1,0	1,0	10	10	65	800	0,8	15	650	4	A
SKPT 21b5	1:1:1	450	1,0	1,0	10	4,5	65	800	0,8	15	440	2,5	B
SKPT 21b5/650	1:1:1	450	1,0	1,0	10	10	65	800	0,8	15	650	4	B
SKPT 22e3/650	3:1:1	280	1,2	0,5	35	10	40	800	0,8	47	650	4	B
SKPT 27a3	1:1	300	0,3	0,3	2	3	76	1200	1	10	650	4	A
SKPT 27b3	1:1:1	300	0,3	0,3	2	3	95	1200	1	10	500	3	B
SKPT 27b3/650	1:1:1	300	0,3	0,2/0,4	2	3	65	1200	1	10	650	4	B
SKPT 27d3,5	3:1	350	0,6	0,3	20	22	100	2500	1	4,7	650	4	A
SKPT 27e3,5	3:1:1	350	0,6	0,3	20	25	110	2500	1	4,7	650	4	B
SKPT 27b4/1300	1:1:1	450	0,1	0,1	0,55	7,5	8,5	2000	0,5	10	1300	6	B
SKPT 27a5	1:1	500	0,4	0,4	5	5	105	2000	1	10	650	4	A

continued on next page

1) Material used is according to UL94-V0. Isolation test and pin distance according to IEC 60664-1(1992); (VDE 0110-1:1997-4)

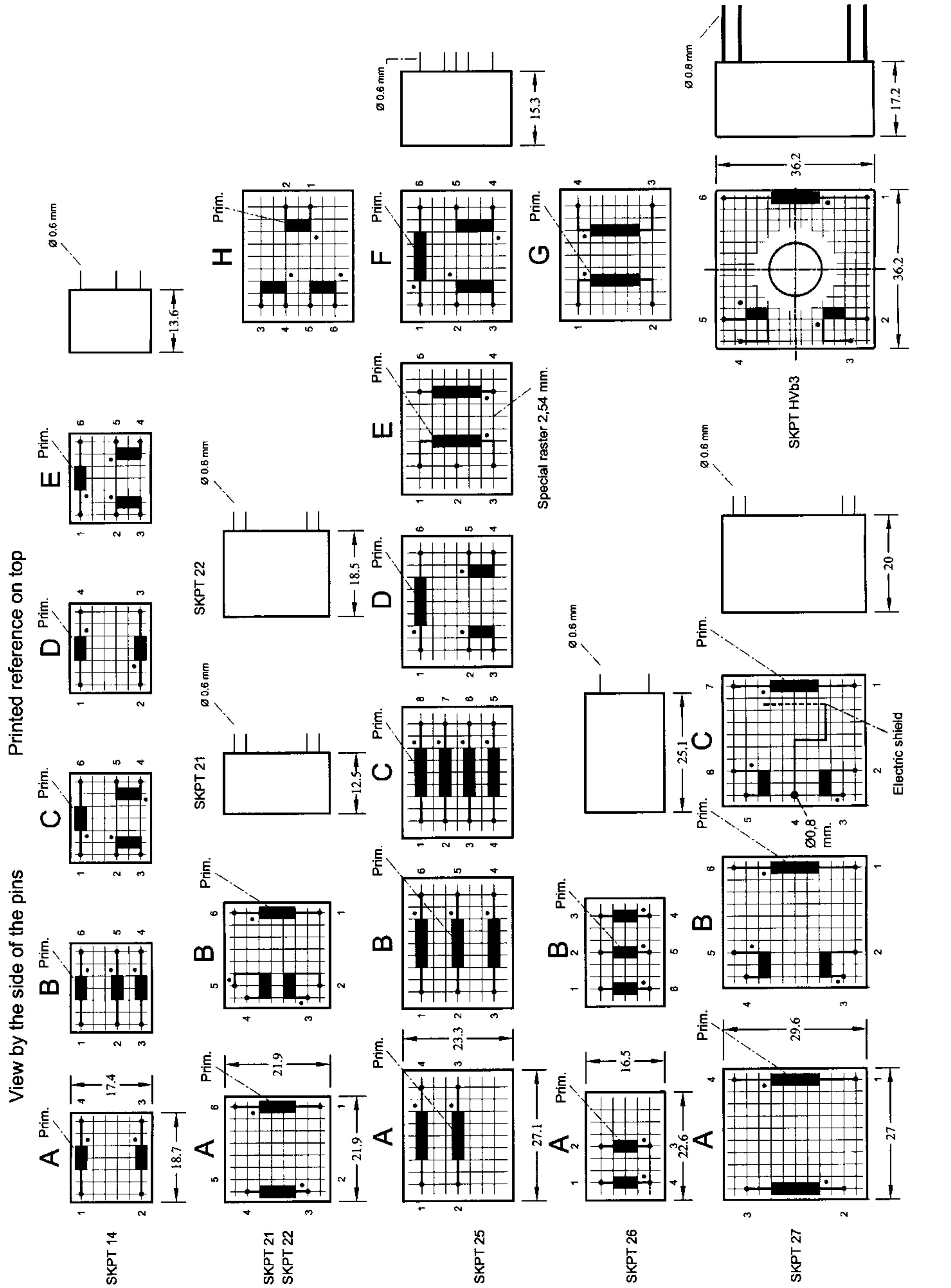
2) Explanations see Chapter A, Section 14.2

14.2 Pulse Transformers (continued)

Types • New Type	N_p/N_s s	$\int V dt$ µVs	R_p Ω	R_s Ω	L_p mH	L_{ss} µH	C_{ps} pF	I_M mA	t_r µs	R_L Ω	V_{ww} V	V_{isol} kV	Win-ding conf
SKPT 27b5	1:1:1	500	0,4	0,4	5	5	117	2000	1	10	500	3	B
SKPT 27b5/650	1:1:1	500	0,4	0,3/0,5	5	5	100	2000	1	10	650	4	B
SKPT 27a10	1:1	1000	0,3	0,3	2,5	5	83	2000	1	10	650	4	A
SKPT 27b10	1:1:1	1000	0,3	0,3	2,5	5	97	2000	1	10	500	3	B
SKPT 27b10/650	1:1:1	1000	0,3	0,2/0,4	2,5	5	84	2000	1	10	650	4	B
SKPT 27b10ES	1:1:1	1000	0,3	0,3	2,5	5	97	2000	1	10	650	4	C
SKPT 27c10	2:1	1000	0,5	0,3	10	15	110	2000	1	10	650	4	A
SKPT HVb3	1:1:1	300	0,3	0,3	3	75	8,5	1000	1	50	3200	12	A
SKPT 25a3/s	1:1	300	0,55	0,55	2	12	20	250	0,8	47	440	3	A
SKPT 25b3/s	1:1:1	300	0,55	0,55	2	12	20	250	0,8	47	440	3	B
SKPT 25e3/s	3:1:1	300	1,8	0,8	15	80	28	250	0,8	47	440	3	B
SKPT 25h3/s	1:1:1:1	300	0,55	0,55	2	12	20	250	0,8	47	440	3	C
SKPT 25a4/s	1:1	400	0,8	0,9	4	17	28	250	0,8	47	440	3	A
SKPT 909	1:1	400	0,8	0,9	4	17	28	600	1	5	900	3	E
SKPT 25b4/s	1:1:1	400	0,8	0,9	4	17	28	250	0,8	47	500	3	B
SKPT 25b4/hs	1:1:1	400	0,8	0,9	1,8	15	28	250	0,8	400	700	4	D
SKPT 25a5/s	1:1	500	1	1,1	5,5	22	28	100 250	0,8 1	100 47	500	3	A
SKPT 25b5/s	1:1:1	500	1,1	1,2	5,5	25	30	100 250	0,8 1	100 47	500	3	B
SKPT 25b6/N	1:1:1	650	1,13	1,2	4,6	20	37	250	1	47	600	4	B
SKPT 25b8/s	1:1:1	800	1,8	2,1	14	40	35	25 250	0,8 1,5	470 47	500	3	B
SKPT 25b10/s	1:1:1	1000	2,2	2,4	18	50	40	25 250	0,8 1,5	470 47	500	3	B
SKPT 25b20/s	1:1:1	2000	6	6	55	100	45	250	3	47	500	3	B

[1] Material used is according to UL94-V0. Isolation test and pin distance according to IEC 60664-1(1992); (VDE 0110-1:1997-4)
[2] Explanations see Chapter A, Section 14.2

Winding Configurations and Dimensions in mm
2,5 mm grid



Current Transformer
TI 300/0,3
300 A / 0,3 A

Absolute Maximum Ratings		
Symbol	**Term**	**Values**
I_1	Max. primary current	300 A
I_2	Max. secondary current	0,3 A
	Precision class sec. current	0,5 %
$\frac{n_s}{n_p}$	Transformer current ratio	1000 : 1
P_{out}	Max. Power output (50/60 Hz)	2 VA
f_{op}	Operating frequency	50 / 60 Hz
R_2	Load resistance [1)]	> 22,2 Ω

TI 300 / 0,3

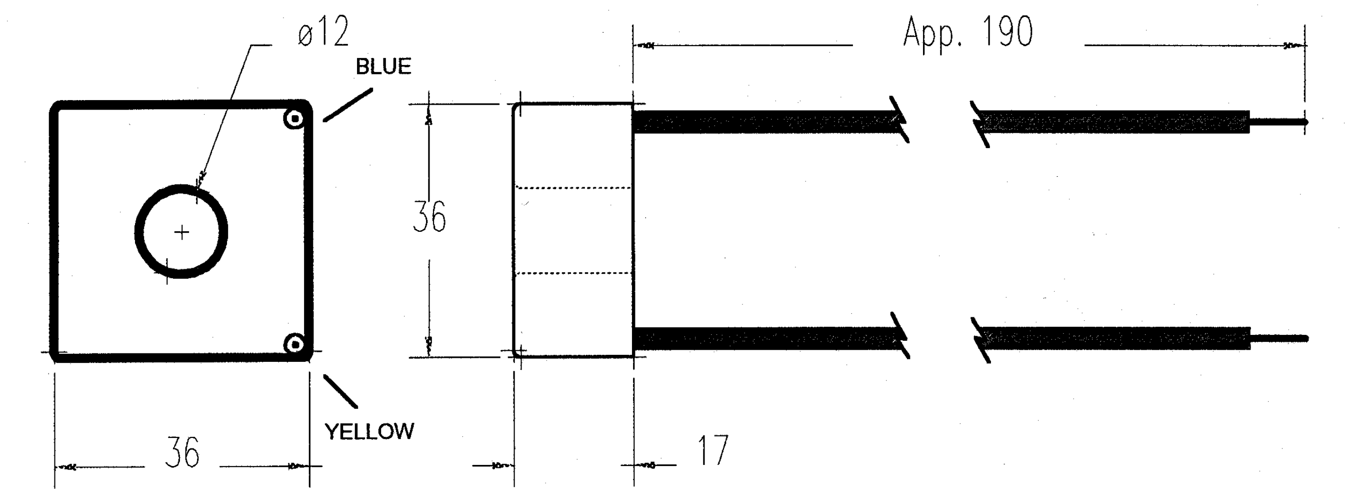


Fig. 1 Outline

Dimensions in mm

El tiristor

Original de:

Universidad de Jaén
Escuela Politécnica Superior

Autor:

Juan Domingo Aguilar Peña

Autorizado para:

http://www.redeya.com

1.1 ESTRUCTURAS Y CARACTERÍSTICAS GENERALES

1.1.1 DESCRIPCIÓN DEL SEMICONDUCTOR Y ESTRUCTURA

El tiristor (SCR) es un dispositivo semiconductor biestable de cuatro capas, PNPN (Fig 1.1), con tres terminales: ánodo (A), cátodo (K) y puerta (G), (Fig. 1.2). Puede conmutar de bloqueo a conducción, o viceversa, en un solo cuadrante.

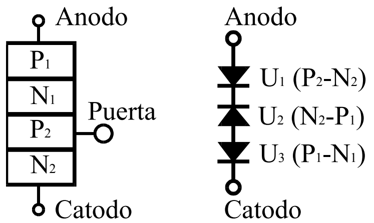


Fig.1.- Estructura del tiristor.

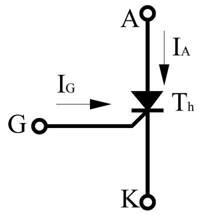


Fig.2.- Símbolo del tiristor.

La curva característica del SCR es la representada en la figura 1.3, donde:

- **V_{DRM}** = Valor máximo de voltaje repetitivo directo.
- **V_{RRM}** = Valor máximo de voltaje repetitivo inverso.
- **V_T** = Caída de tensión de trabajo.
- **I_T** = Intensidad directa de trabajo.
- **I_H** = Intensidad de mantenimiento en estado de conducción.
- **I_{DRM}** = Intensidad directa en estado de bloqueo.
- **I_{RRM}** = Intensidad inversa en estado de bloqueo.

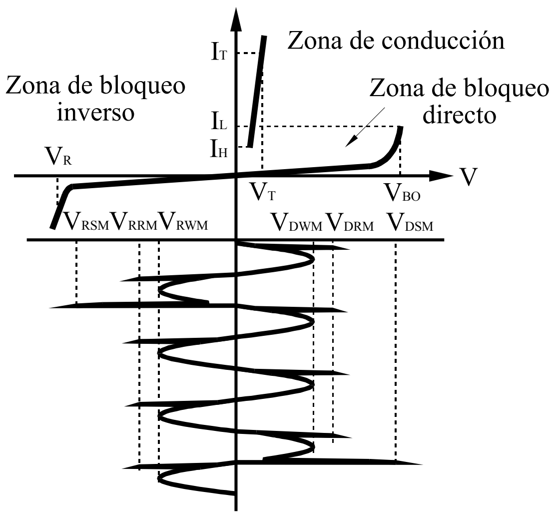


Fig.3.- Curva característica del tiristor.

1.1.2 MODOS DE FUNCIONAMIENTO

- $V_{AK} < 0 \Rightarrow$ <u>Zona de bloqueo inverso</u>: SCR bloqueado (circuito abierto) (Fig. 1.3).
  - Solo lo recorre una débil corriente de fuga inversa (I_{RRM}).
  - Hay que intentar no sobrepasar la tensión inversa máxima (V_{RRM}).

- $V_{AK} > 0$; sin excitar puerta$\Rightarrow$ <u>Zona de bloqueo directo:</u> SCR bloqueado (circ. abierto).
  - Solo lo recorre una débil corriente de fuga directa (I_{DRM}).
  - Hay que intentar no sobrepasar la tensión directa máxima (V_{DRM}) (Fig. 1.3).

- $V_{AK} > 0$; excitada en puerta, $\Rightarrow$ <u>Zona de conducción</u>: SCR conduce (cortocircuito).
  - entre G y K circula un impulso positivo de corriente (Fig. 1.3).
  - Duración del impulso de cebado: lo suficiente para que $I_A = I_L$ (de enganche).
  - Mientras el SCR conduce, este se comporta como un diodo.

- El SCR se bloquea cuando la corriente directa (I_T) < corriente de mantenimiento (I_H), en cuyo caso la puerta pierde todo poder sobre el SCR.

- Los modos de funcionamiento del SCR pueden ser:

  - <u>Todo o nada</u>: para una señal de entrada (Fig. 1.4.a), el SCR suprime algunos semiperíodos suministrando a la carga paquetes de semiondas (Fig. 1.4.b).

  - <u>Ángulo de fase</u>: (Fig. 1.4 c) se mantienen todos los semiperíodos, se suprime parte de cada uno de ellos (ángulo de bloqueo) y el resto se transmite a la carga (ángulo de conducción).

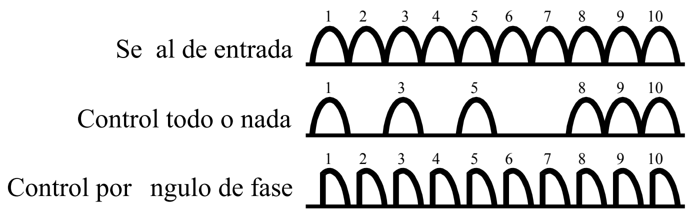


Fig..4.- Modos de funcionamiento del tiristor.

1.1.3 CARACTERÍSTICAS GENERALES

- Interruptor casi ideal.
- Soporta tensiones altas.
- Amplificador eficaz.
- Es capaz de controlar grandes potencias.
- Fácil controlabilidad.
- Relativa rapidez.
- Características en función de situaciones pasadas (memoria).

1.2 CARACTERÍSTICAS ESTÁTICAS

Corresponden a la región ánodo-cátodo. Son aquellos valores que determinan las posibilidades máximas de un determinado SCR. Estos datos son:

- Tensión inversa de pico de trabajo .... V_{RWM}
- Tensión directa de pico repetitiva .... V_{DRM}
- Tensión directa .... V_T
- Corriente directa media .... I_{TAV}
- Corriente directa eficaz .... I_{TRMS}
- Corriente directa de fugas .... I_{DRM}
- Corriente inversa de fugas .... I_{RRM}
- Corriente de mantenimiento .... I_H

Las características térmicas a tener en cuenta al trabajar con tiristores son:

- Temperatura de la unión .... T_j
- Temperatura de almacenamiento .... T_{stg}
- Resistencia térmica contenedor-disipador .... $R_{c\text{-}d}$
- Resistencia térmica unión-contenedor .... $R_{j\text{-}c}$
- Resistencia térmica unión-ambiente .... $R_{j\text{-}a}$
- Impedancia térmica unión-contenedor .... $R_{j\text{-}c}$

1.3 CARACTERÍSTICAS DE CONTROL

Corresponden a la región puerta-cátodo y determinan las propiedades del circuito de mando que responde mejor a las condiciones de disparo. Los fabricantes definen las siguientes características:

- Tensión directa máx. .... V_{GFM}
- Tensión inversa máx. .... V_{GRM}
- Corriente máxima .... I_{GM}
- Potencia máxima .... P_{GM}
- Potencia media .... P_{GAV}
- Tensión puerta-cátodo para el encendido .... V_{GT}
- Tensión residual máxima que no enciende ningún elemento ..... V_{GNT}
- Corriente de puerta para el encendido .... I_{GT}
- Corriente residual máxima que no enciende ningún elemento ... I_{GNT}

1.3.1 ÁREA DE DISPARO SEGURO

En este área (Fig. 1.5) se obtienen las condiciones de disparo del SCR. Las tensiones y corrientes admisibles para el disparo se encuentran en el interior de la zona formada por las curvas:

- **Curva A y B**: límite superior e inferior de la tensión puerta-cátodo en función de la corriente positiva de puerta, para una corriente nula de ánodo.
- **Curva C**: tensión directa de pico admisible V_{GF}.
- **Curva D**: hipérbola de la potencia media máxima P_{GAV} que no debemos sobrepasar.

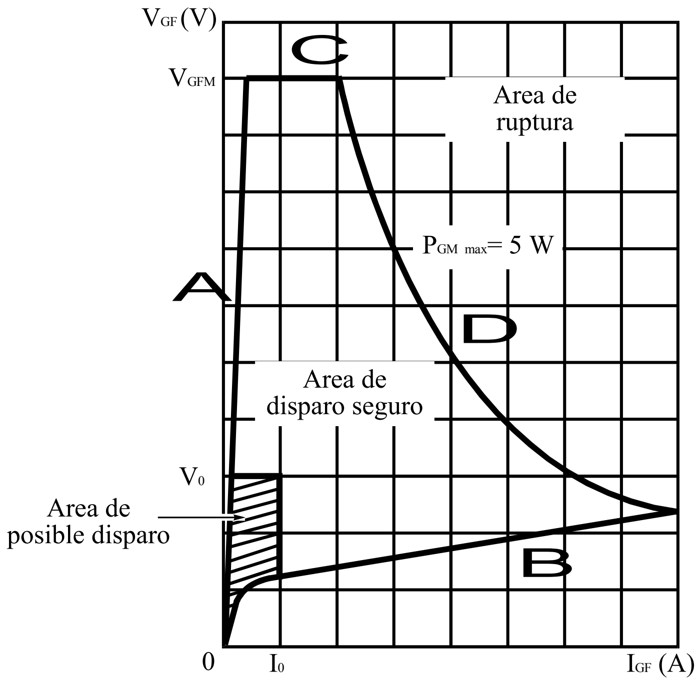


Fig.5.- Curva características de puerta del tiristor.

1.4 CARACTERÍSTICAS DINÁMICAS

1.4.1 CARACTERÍSTICAS DINÁMICAS

- ***Tensiones transitorias***:

  - Valores de la tensión superpuestos a la señal de la fuente de alimentación.
  - Son breves y de gran amplitud.
  - La tensión inversa de pico no repetitiva (V_{RSM}) debe estar dentro de esos valores.

- ***Impulsos de corriente***:

  - Para cada tiristor se publican curvas que dan la cantidad de ciclos durante los cuales puede tolerarse una corriente de pico dada. (Fig. 1.6).
  - A mayor valor del impuso de corriente, menor es la cantidad de ciclos.
  - El tiempo máximo de cada impulso está limitado por la $T^{\underline{ra}}$ media de la unión.

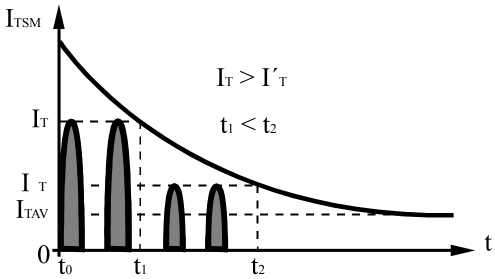


Fig.6.- Curva de limitación de impulsos de corriente

- ***Ángulos de conducción***: (Fig. 1.7)

  - La corriente y tensión media de un SCR dependen del ángulo de conducción.
  - A mayor ángulo de conducción, se obtiene a la salida mayor potencia.
  - Un mayor ángulo de bloqueo o disparo se corresponde con un menor ángulo de conducción:

àngulo de conducción = 180º−àngulo de disparo

  - Conociendo la variación de la potencia disipada en función de los diferentes ángulos de conducción podremos calcular las protecciones necesarias.

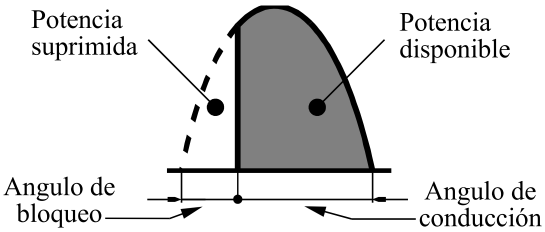


Fig.7.- Ángulo de bloqueo y conducción de un tiristor.

1.4.2 CARACTERÍSTICAS DE CONMUTACIÓN

Los tiristores no son interruptores perfectos, necesitan un tiempo para pasar de corte a conducción y viceversa. Vamos a analizar este hecho.

1.4.2.1 TIEMPO DE ENCENDIDO (T_{ON})

Tiempo que tarda el tiristor en pasar de corte a conducción (Fig. 1.8).

- ***Tiempo de retardo (t_d)***: tiempo que transcurre desde que la corriente de puerta alcanza el 50 % de su valor final hasta que la corriente de ánodo alcanza el 10 % de su valor máximo.

- ***Tiempo de subida (t_r)***: tiempo necesario para que la corriente de ánodo pase del 10 % al 90 % de su valor máximo, o, el paso de la caída de tensión en el tiristor del 90 % al 10 % de su valor inicial.

$$t_{on} = t_d + t_r$$

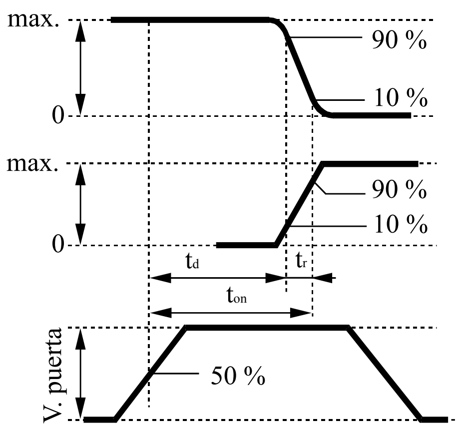


Fig.8.- Tiempo de encendido T_{on}.

1.4.2.2 TIEMPO DE APAGADO (T_{OFF})

Tiempo que tarda el tiristor en pasar de conducción a corte (Fig. 1.9).

- ***Tiempo de recuperación inversa (t_{rr})***: tiempo en el que las cargas acumuladas en la conducción del SCR, por polarización inversa de este, se eliminan parcialmente.

- ***Tiempo de recuperación de puerta (t_{gr})***: tiempo en el que, en un número suficiente bajo, las restantes cargas acumuladas se recombinan por difusión, permitiendo que la puerta recupere su capacidad de gobierno.

$$t_{off} = t_{rr} + t_{gr}$$

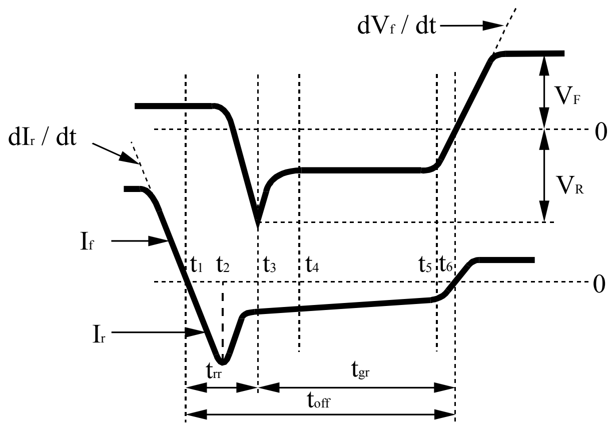


Fig.9.- Tiempo de apagado T_{off}.

1.4.3 MODOS DE EXTINCIÓN DEL TIRISTOR

1.4.3.1 EXTINCIÓN POR CONTACTO MECÁNICO

Extinción del SCR interrumpiendo el circuito mediante un cortocircuito (Fig.1.10 a-b) o introduciendo una corriente inversa usando una fuente auxiliar (Fig.1.10 c) o un condensador cargado (Fig.1.10 d-e).

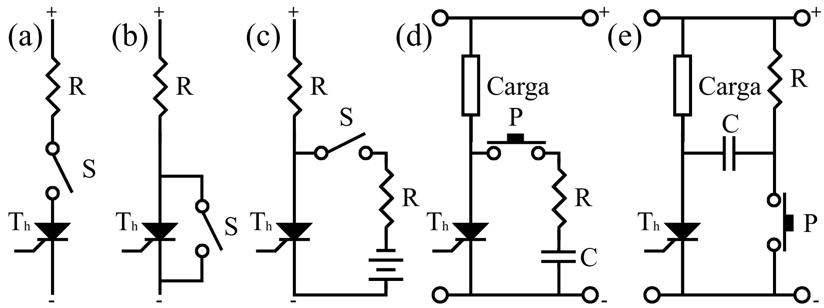


Fig.10.- Formas de extinción por contacto mecánico.

1.4.3.2 EXTINCIÓN POR CONMUTACIÓN FORZADA

Se fuerza a la corriente a pasar a través del tiristor en sentido inverso, consiguiendo un tiempo de descebado menor.

- ***Conmutación forzada por autoconmutación***: circuitos que desceban al SCR automáticamente tras un tiempo predeterminado desde la aplicación del impulso de disparo. Los más usados son:

  - Circuito oscilante LC en paralelo: C cargado ⇒ disparo del SCR ⇒ C se descarga sobre SCR en sentido directo ⇒ por oscilación del circuito LC, C se carga en sentido opuesto hasta que I_R (de carga) < I_{GT} ⇒ se produce el descebado (Fig. 1.11).

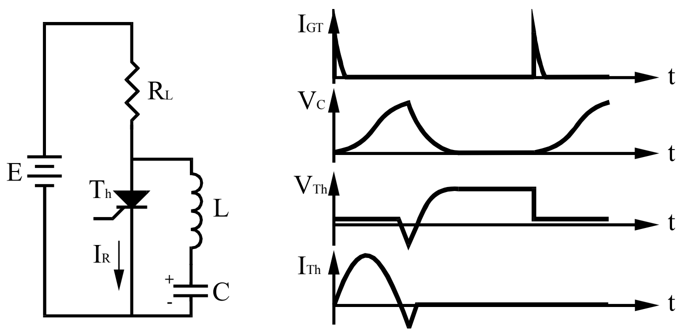


Fig.11.- Extinción por circuito LC en paralelo.

– Circuito oscilante LC en serie: La I que circula al disparar el SCR excita al circuito LC, pasado el 1[er] semiciclo de la oscilación, la I se invierte y desceba el SCR (Fig. 1.12).

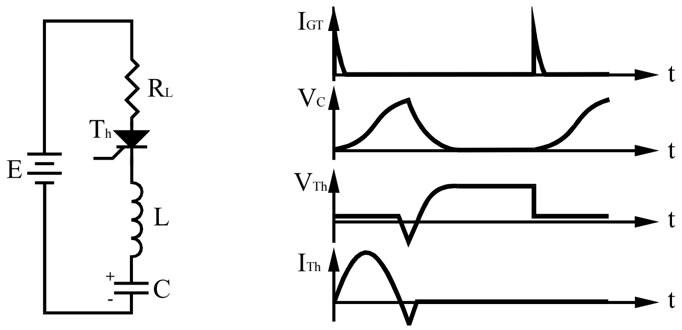


Fig.12.- Extinción por circuito LC en serie.

- ***Conmutación forzada por medios exteriores***: circuitos que desceban al SCR sin depender del tiempo en que se produjo el disparo. Los más usados son:

  – Conmutación por medio de C.A.: el SCR se desceba cada vez que cambia el sentido de la tensión al semiperíodo negativo (Fig. 1.13). La frecuencia no debe superar al tiempo de conmutación.

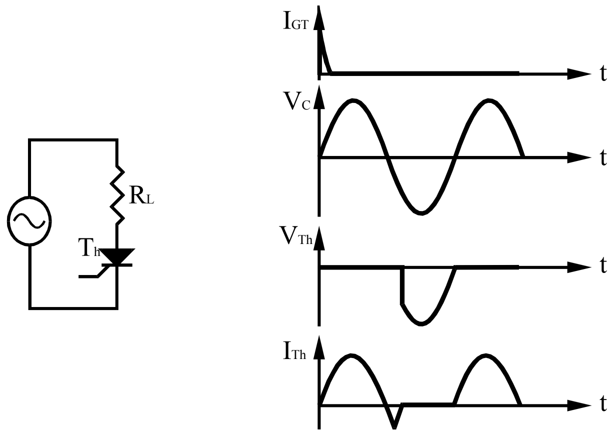


Fig.13.- Circuito de conmutación por medio de C.A.

– <u>Conmutación por tiristor auxiliar</u>: si T_1 conduce y T_2 está en corte ⇒ C se carga por T_1; cuando T_2 conmuta a conducción ⇒ T_1 se bloquea ⇒ C se carga por R_L en sentido inverso; pasado un tiempo t_q, que depende de C y debe ser > t_{off} del SCR ⇒ la tensión en T_1 (V_{T1}) tiende a hacerse positiva (Fig. 1.14).

$$\mathbf{V_{Th1} = V - R_L \cdot I(t) = V \cdot \left(1 - 2e^{-t/R_L C}\right)}$$

$$\mathbf{t_q \geq 0{,}7 \cdot R_L \cdot C}$$

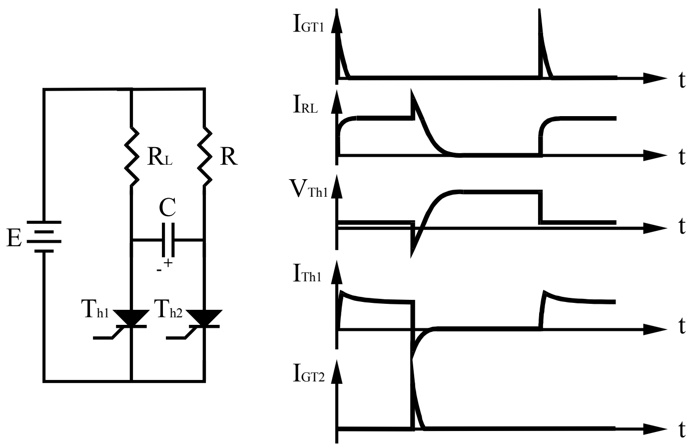


Fig.14.- Circuito de conmutación por tiristor auxiliar.

1.5 MÉTODOS DE DISPARO

Para producir el disparo del SCR: $I_{AK} > I_L$. Para mantenerse en la zona de conducción, por el SCR debe circular I_H , por debajo de la cual el SCR se bloquearía.

1.5.1 MÉTODOS DE DISPARO

1.5.1.1 DISPARO POR PUERTA

- En la figura 1.15 tenemos un circuito de disparo por puerta.
- El valor requerido de V_T necesario para disparar el SCR es: $\boxed{V_T = V_G + I_G \cdot R}$
- R viene dada por la pendiente de la recta tangente a la curva de máxima disipación de potencia (Fig 1.16) para obtener la máxima seguridad en el disparo. $\boxed{R = V_{FG} / I_{FG}}$
- Una vez disparado el SCR perdemos el control en puerta.
- Las condiciones de bloqueo se recobran cuando $V_{AK} < V_H$ y cuando $I_{AK} < I_H$

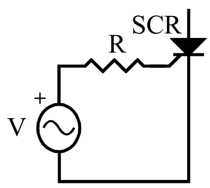


Fig.15.- Circuito de control por puerta de un SCR

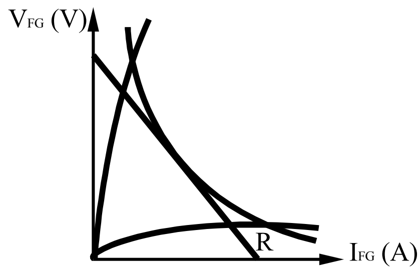


Fig.16.- Recta tangente a la curva de máx. disipación de potencia

1.5.1.2 DISPARO POR MÓDULO DE TENSIÓN

Es el debido al mecanismo de multiplicación por avalancha.

1.5.1.3 DISPARO POR GRADIENTE DE TENSIÓN

Una subida brusca del potencial de ánodo en el sentido directo de conducción provoca el disparo (Fig. 1.17). Este caso más que un método, se considera un inconveniente.

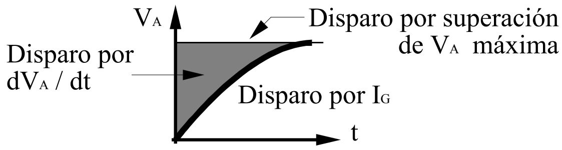


Fig.17.- Zona de disparo por gradiente de tensión.

1.5.1.4 DISPARO POR RADIACIÓN

Está asociado a la creación de pares electrón-hueco por la absorción de la luz del elemento semiconductor. El SCR activado por luz se llama LASCR.

1.5.1.5 DISPARO POR TEMPERATURA

Asociado al aumento de pares electrón-hueco generados y recogidos por la unión N_2-P_1 de la estructura del SCR (Fig. 1.1).

La tensión de ruptura V_{BR} (si se alcanza durante 10 ms, el SCR puede destruirse) permanece cte. hasta un cierto valor de la T^{ra} y después disminuye al aumentar esta.

1.5.2 CONDICIONES NECESARIAS PARA EL CONTROL DE UN SCR

- Disparo: – Ánodo positivo respecto al cátodo.
  – La puerta debe recibir un pulso positivo con respecto al cátodo.
  – En el momento del disparo $I_{AK} > I_L$

- Corte: – Anulamos la tensión V_A
  – Incrementamos R_L hasta que $I_{ak} < I_H$

1.6 LIMITACIONES DEL TRANSISTOR

1.6.1 LIMITACIONES DE LA FRECUENCIA DE FUNCIONAMIENTO

- La frecuencia de trabajo en los SCR no puede superar ciertos valores.
- El límite es atribuible a la duración del proceso de apertura y cierre del dispositivo.
- La frecuencia rara vez supera los 10 Khz.

1.6.2 LIMITACIONES DE LA PENDIENTE DE TENSIÓN dv/dt

dv/dt es el valor mínimo de la pendiente de tensión por debajo del cual no se producen picos transitorios de tensión de corta duración, gran amplitud y elevada velocidad de crecimiento.

A) CAUSAS

- ***La alimentación principal*** produce transitorios difíciles de prever en aparición, duración (inversamente proporcional a su amplitud) y amplitud.
- ***Los contactores entre la alimentación de tensión y el equipo***: cuya apertura y cierre pueden producir transitorios de elevada relación dv/dt (hasta 1.000 V/μs) produciendo el basculamiento del dispositivo.
- ***La conmutación de otros tiristores cercanos*** que introducen en la red picos de tensión.

B) EFECTOS

- Puede provocar el cebado del tiristor, perdiendo el control del dispositivo.
- La dv/dt admisible varia con la temperatura.

1.6.3 LIMITACIONES DE LA PENDIENTE DE INTENSIDAD di/dt

di/dt es el valor mínimo de la pendiente de la intensidad por debajo de la cual no se producen puntos calientes.

A) CAUSAS

- Durante el cebado, la zona de conducción se reduce a una parte del cátodo cerca de la puerta, si el circuito exterior impone un crecimiento rápido de la intensidad, en esta zona la densidad de corriente puede alcanzar un gran valor.
- Como el cristal no es homogéneo, existen zonas donde la densidad de Intensidad es mayor (puntos calientes).

B) EFECTOS

- En la conmutación de bloqueo a conducción la potencia instantánea puede alcanzar valores muy altos.
- La energía disipada producirá un calentamiento que, de alcanzar el límite térmico crítico, podría destruir el dispositivo.

1.6.4 PROTECCIONES CONTRA dv/dt Y di/dt

- Solución: colocar una red RC en paralelo con el SCR y una L en serie (Fig. 1.18).
- Calculo: método de la constante de tiempo y método de la resonancia.

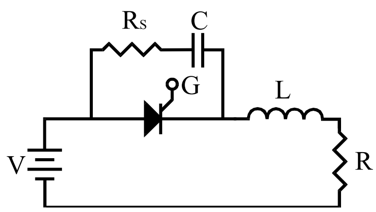


Fig.18.- Circuito de protección contra dv/dt y di/dt

1.6.4.1 MÉTODO DE LA CONSTANTE DE TIEMPO

- ***Cálculo de R y C***:

1.- Hallamos el valor mínimo de la cte. de tiempo τ de la dv/dt:
donde V_{DSM} = V de pico no repetitiva de bloqueo directo.

Calculamos el valor de R y C:

$$\tau = \frac{0{,}63 \cdot V_{DSM}}{(dv/dt)_{min}}$$

$$C = \frac{\tau}{R_L} \qquad R_s = \frac{V_{A(max)}}{\left(I_{TSM} - I_L\right) \cdot \Gamma}$$

I_L = corriente en la carga
R_L = resistencia de carga.
I_{TSM} = corriente directa de pico no repetitiva.
V_A = tensión de ánodo.
Γ = coeficiente de seguridad (de 0,4 a 0,1).

2.- Hallamos el valor de R_{min} que asegura la no superación de la di/dt máxima especificada (a partir de la ecuación de descarga de C):

$$R_{min} = \frac{\sqrt{V_{A(max)}}}{(di/dt) \cdot C}$$

- ***Cálculo de L***:

$$L = \frac{V_{A(max)}}{(di/dt)}$$

1.6.4.2 MÉTODO DE LA RESONANCIA

- Elegimos R, L y C para entrar en resonancia
- El valor de la frecuencia es: $f = \frac{dv/dt}{2\pi \cdot V_{A(max)}}$
- en resonancia: $f = \frac{1}{2\pi \cdot \sqrt{LC}} \Rightarrow C = \frac{1}{(2\pi f)^2 \cdot L}$
- El valor de L es el que más nos interese, normalmente: $L = 50\ \mu H$
- El valor de R será: $R_s = \frac{\sqrt{L}}{C}$

1.6.5 LIMITACIONES DE LA TEMPERATURA

- Hallamos la potencia que disipa el dispositivo sin radiador: $P_{(AV)} = \frac{T_j - T_a}{R_{ja}}$
- Hallamos el valor de la intensidad media de conducción ($I_{T(AV)}$) para el factor de forma ***a*** de un ángulo de conducción dado:

$$a = \frac{I_{T(RMS)}}{I_{T(AV)}} \Rightarrow I_{T(AV)} = \frac{I_{T(RMS)}}{a} \qquad \left(I_{T(RMS)} = \frac{P_L}{V_{e(RMS)}} \right)$$

- Observando las curvas de disipación de potencia (Fig. 1.19) obtenemos la potencia disipada sin radiador, si esta es menor que la teórica, el dispositivo necesita radiador.

- De dichas las curvas obtenemos el valor de la R_{ca} (contenedor-ambiente) que, para una R_{cd} (contenedor-disipador) dada obtenemos el valor de la resistencia térmica del disipador:

$$\boxed{\mathbf{R_d = R_{ca} - R_{cd}}}$$

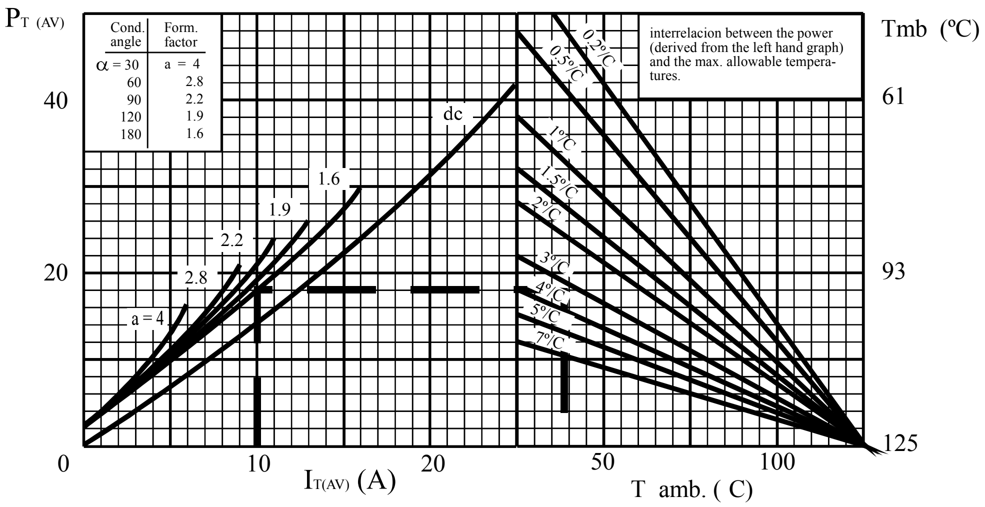


Fig.19.- Relación entre la potencia y la temperatura para una intensidad dada.

INDICE

SEMIKRON

Thyristors

SKT 10
SKT 16
SKT 24

V_{RSM}	V_{RRM} V_{DRM}	$\left(\frac{dv}{dt}\right)_{cr}$	I_{TRMS} (maximum values for continuous operation) 30 A	40 A	50 A
			I_{TAV} (sin. 180; T_{case} = . . . °C)		
V	V	V/µs	19 A (95 °C)	25 A (74 °C)	32 A (72 °C)
500	400	500	–	**SKT 16/04 D**	**SKT 24/04 D**
700	600	500	**SKT 10/06 D**	**SKT 16/06 D***	–
900	800	500	**SKT 10/08 D**	**SKT 16/08 D**	**SKT 24/08 D**
1100	1000	500	**SKT 10/10 D**	–	–
1300	1200	500	**SKT 10/12 D**	–	–
		1000	**SKT 10/12 E**	**SKT 16/12 E***	**SKT 24/12 E***
1500	1400	1000	–	**SKT 16/14 E**	**SKT 24/14 E**
1700	1600	1000	–	**SKT 16/16 E**	**SKT 24/16 E***

Symbol	Conditions	SKT 10	SKT 16	SKT 24	Units
I_{TAV}	sin. 180; (T_{case} = . . .)	10 (106)	16 (103)	24 (94)	A °C
I_{TSM}	T_{vj} = 25 °C; 10 ms	250	370	450	A
	T_{vj} = 130 °C; 10 ms	210	330	380	A
i^2t	T_{vj} = 25 °C; 8,35 ... 10 ms	310	680	1000	A^2s
	T_{vj} = 130 °C; 8,35 ... 10 ms	220	550	720	A^2s
t_{gd}	T_{vj} = 25 °C; I_G = 1 A; di_G/dt = 1 A/µs		typ. 1		µs
t_{gr}	V_D = 0,67 · V_{DRM}		typ. 2		µs
$(di/dt)_{cr}$	f = 50 . . . 60 Hz		50		A/µs
I_H	T_{vj} = 25 °C		typ. 80; max. 150		mA
I_L	T_{vj} = 25 °C		typ. 150; max. 300		mA
t_q	T_{vj} = 130 °C; typ.		80		µs
V_T	T_{vj} = 25 °C; (I_T = ...); max.	1,6 (30)	2,4 (75)	1,9 (75)	V A
$V_{T(TO)}$	T_{vj} = 130 °C	1,0	1,0	1,0	V
r_T	T_{vj} = 130 °C	18	20	10	mΩ
I_{DD}, I_{RD}	T_{vj} = 130 °C; $V_{DD} = V_{DRM}$; $V_{RD} = V_{RRM}$	4	8	8	mA
V_{GT}	T_{vj} = 25 °C		3		V
I_{GT}	T_{vj} = 25 °C		100		mA
V_{GD}	T_{vj} = 130 °C		0,25		V
I_{GD}	T_{vj} = 130 °C		3		mA
R_{thjc}	cont.	1,2	0,8		°C/W
	sin. 180/rec. 120	1,3/1,35	0,9/0,95		°C/W
R_{thch}		1,0	0,5		°C/W
T_{vj}			– 40 ... +130		°C
T_{stg}			– 55 ... +150		°C
M	SI units US units	2,0 18	2,5 22		Nm lb. in.
a		5 · 9,81	5 · 9,81		m/s^2
w		7	12		g
Case		B 1	B 2		

Features

- Hermetic metal cases with glass insulators
- Threaded studs ISO M5 and M6 or UNF 1/4-28
- International standard cases

Typical Applications

- DC motor control (e. g. for machine tools)
- Controlled rectifiers (e. g. for battery charging)
- AC controllers (e. g. for temperature control)

* Available with UNF thread 1/4-28 UNF2A, e.g. SKT 16/06 D UNF

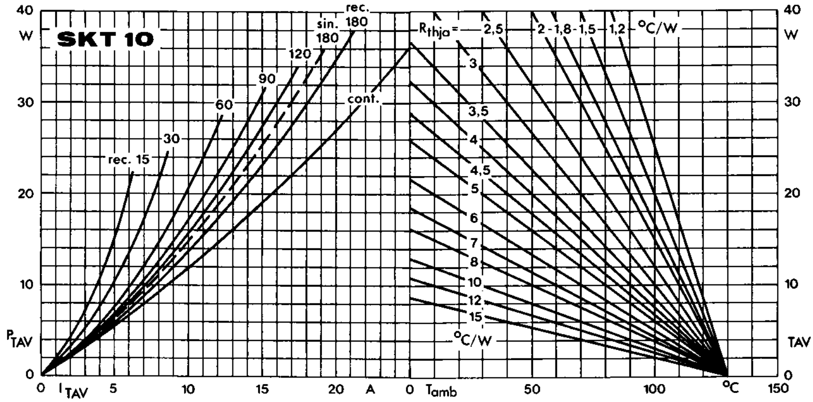


Fig. 1 a Power dissipation vs. on-state current and ambient temperature

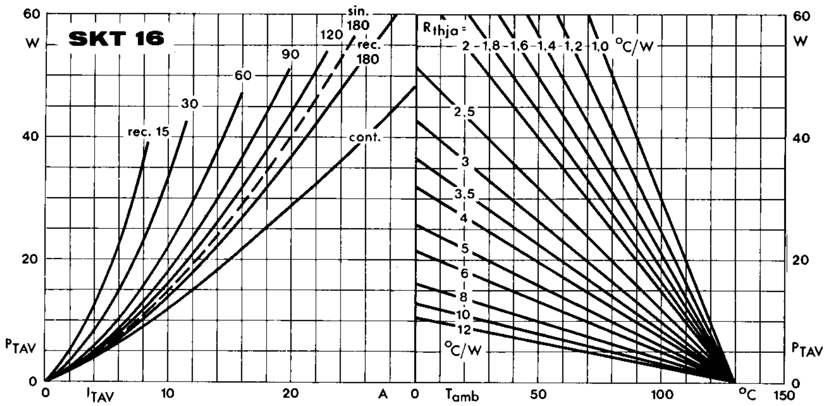


Fig. 1 b Power dissipation vs. on-state current and ambient temperature

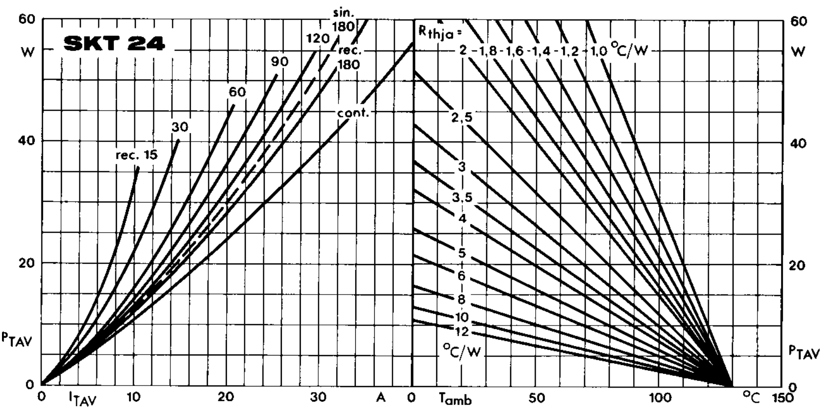


Fig. 1 c Power dissipation vs. on-state current and ambient temperature

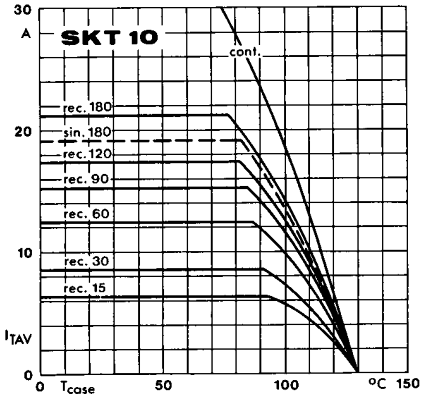


Fig. 2 a Rated on-state current vs. case temperature

Fig. 2 b

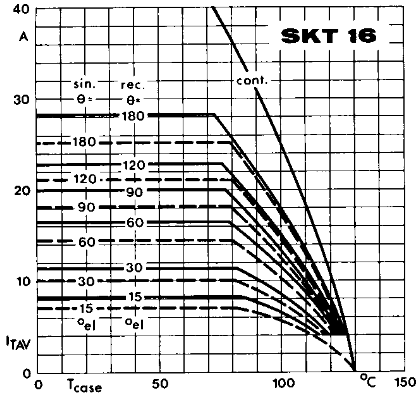


Fig. 2 b Rated on-state current vs. case temperature

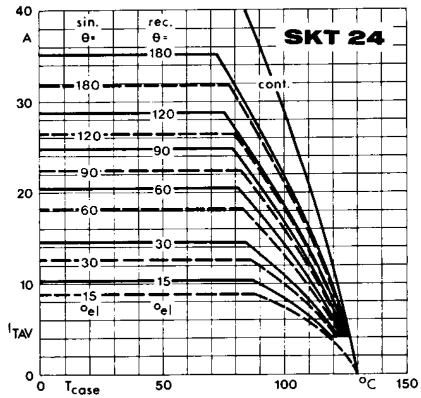


Fig. 2 c Rated on-state current vs. case temperature

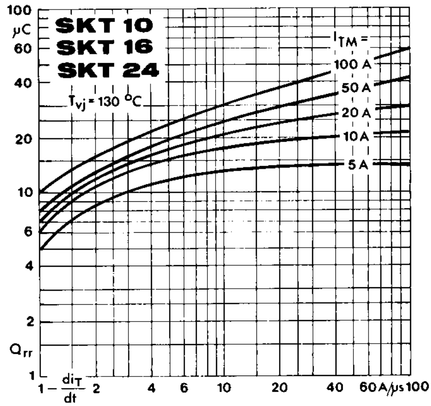
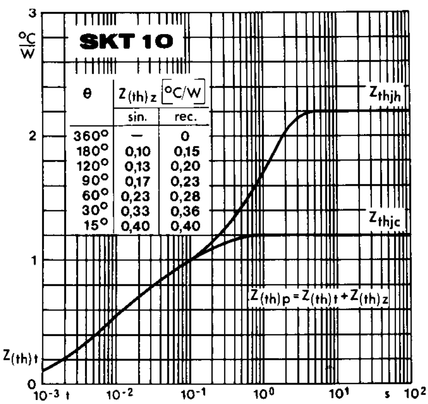


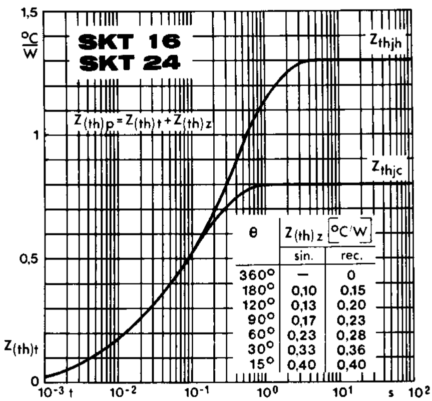
Fig. 3 Recovered charge vs. current decrease



θ	Z(th)z [°C/W] sin.	rec.
360°	—	0
180°	0,10	0,15
120°	0,13	0,20
90°	0,17	0,23
60°	0,23	0,28
30°	0,33	0,36
15°	0,40	0,40

Fig. 4 a Transient thermal impedance vs. time

Fig. 4 b



θ	Z(th)z [°C/W] sin.	rec.
360°	—	0
180°	0,10	0,15
120°	0,13	0,20
90°	0,17	0,23
60°	0,23	0,28
30°	0,33	0,36
15°	0,40	0,40

Fig. 4 b Transient thermal impedance vs. time

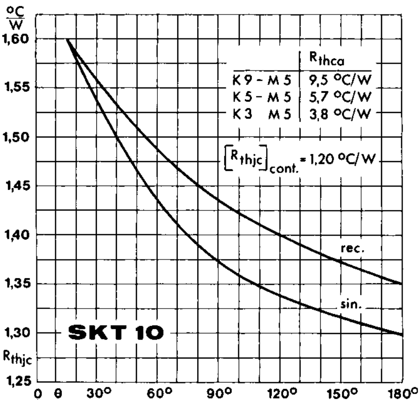


Fig. 5 a Thermal resistance vs. conduction angle

Fig. 5 b

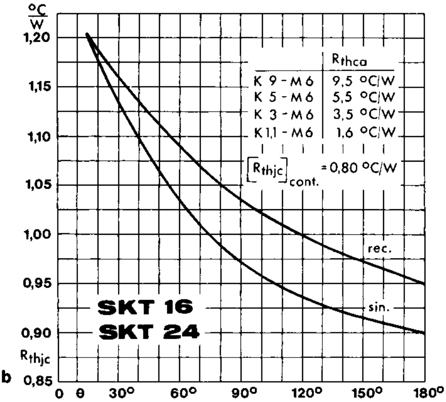


Fig. 5 b Thermal resistance vs. conduction angle

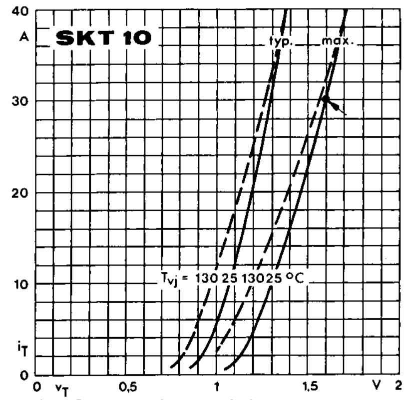


Fig. 6 a On-state characteristics

Fig. 6 b

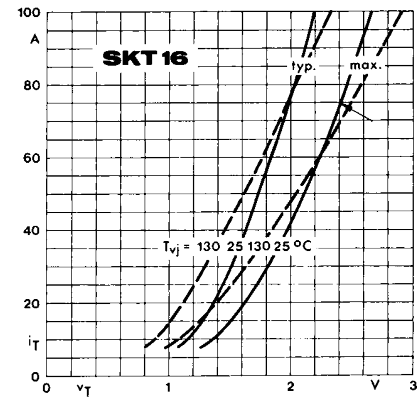


Fig. 6 b On-state characteristics

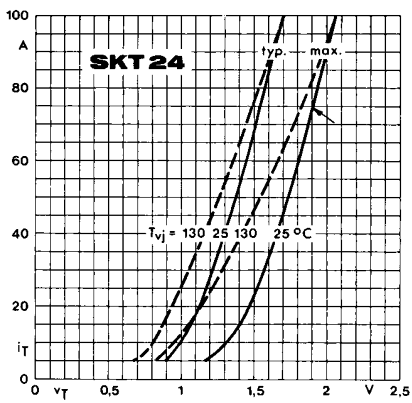


Fig. 6 c On-state characteristics

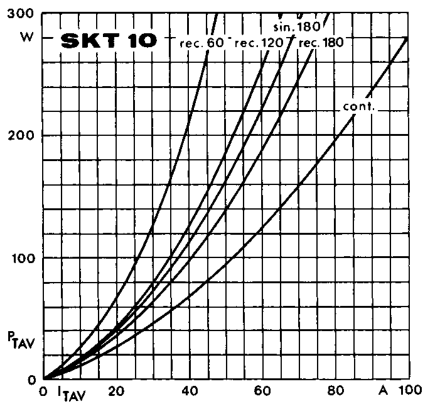


Fig. 7 a Power dissipation vs. on-state current

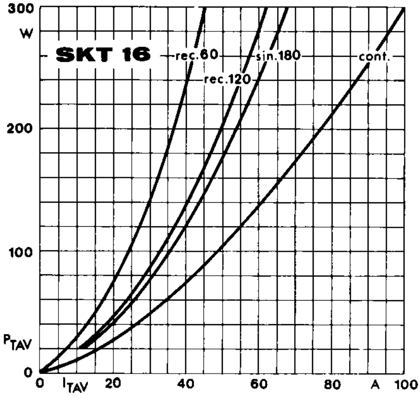


Fig. 7 b Power dissipation vs. on-state current

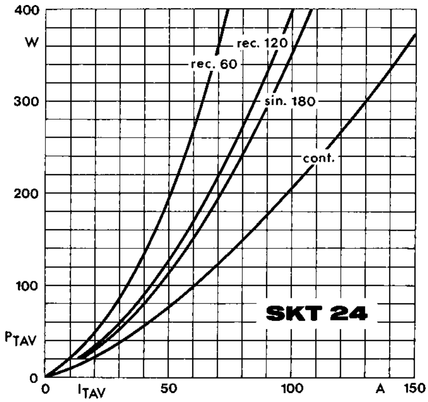
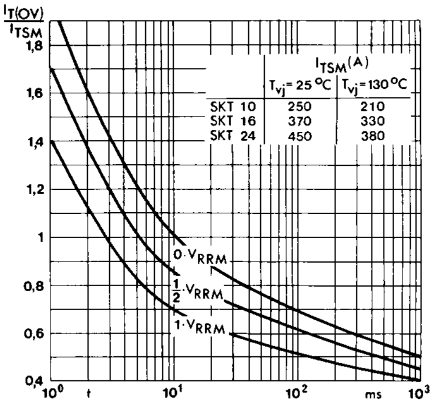


Fig. 7 c Power dissipation vs. on-state current



	I_{TSM} (A)	
	T_{vj} = 25 °C	T_{vj} = 130 °C
SKT 10	250	210
SKT 16	370	330
SKT 24	450	380

Fig. 8 Surge overload current vs. time

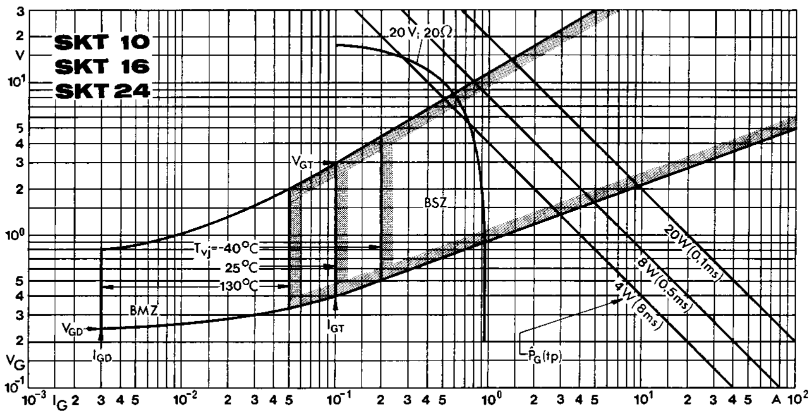
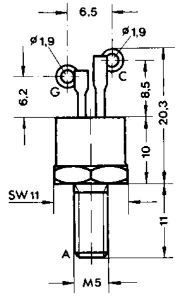


Fig. 9 Gate trigger characteristics

SKT 10

Case B 1

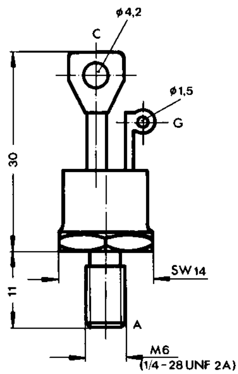
IEC-Publ. 191-2: A 13 M
DIN 41891: 200 B 3
BS 3934: SO – 35 A
JEDEC: TO – 208 AB (TO – 64) metric



SKT 16
SKT 24

Case B 2

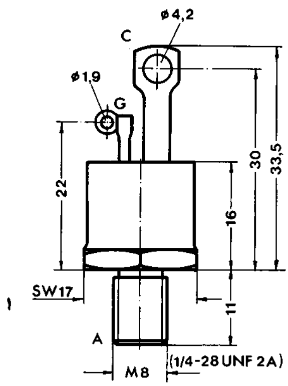
IEC-Publ. 191-2: A 11 M, A 11 U
DIN 41892: 201 C 3
BS 3934: SO – 36
JEDEC: TO – 208 AA (TO – 48)



SKT 40
SKT 50

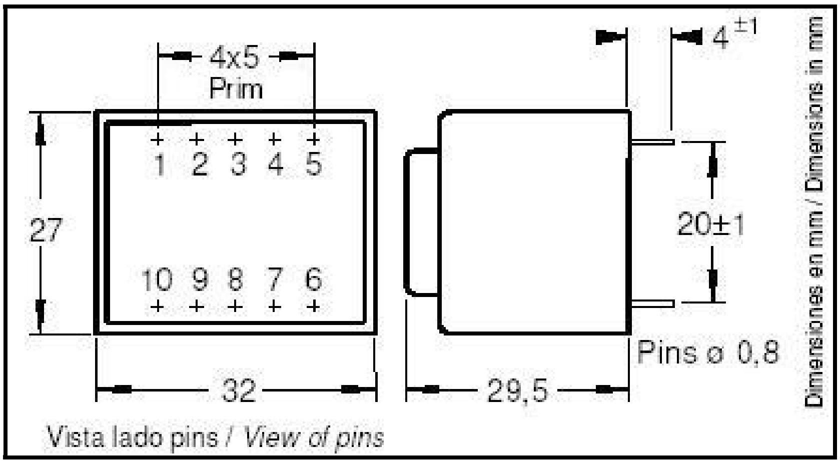
Case B 3

IEC-Publ. 191-2: A 38 MA, A 14 U
DIN 41892: 202 C 3
BS 3934: SO – 28
JEDEC: TO – 208 AC (TO – 65)



C: Cathode terminal
A: Anode terminal
G: Gate terminal

Dimensions in mm



Referencia	Pins primario	Pins secundario	Weight (Kg)
4XX928 305XX928	1-5	7-9	0,113Kg
5XX928 307XX928	1-5	6-8-10	
6XX928 306XX928	1-5	6-7 / 9-10	
303XX923 308XX923	1-5	7-9	0,113Kg
304XX923 309XX923	1-5	6-7 / 9-10	

Close this window

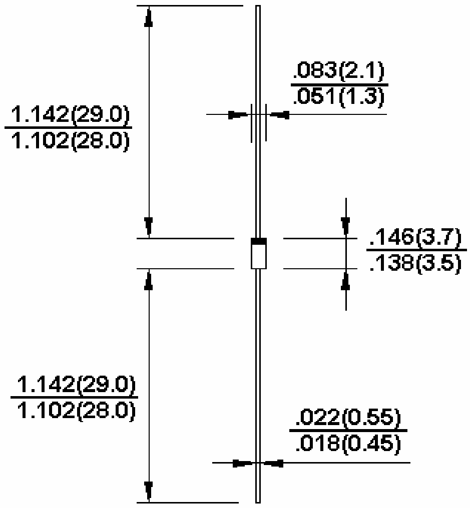
TAIWAN SEMICONDUCTOR

Pb RoHS COMPLIANCE

BZX55C SERIES

500mW Hermetically Sealed
Glass Zener Voltage Regulators

DO-35



Dimensions in inches and (millimeters)

Features

- Zener Voltage range 2.0 to 75 volts
- DO-35 package (JEDEC)
- Through-hole device type mounting
- Hermetically sealed glass
- Compression bonded construction
- All external surfaces are corrosion resistant and leads are readily solderable
- RoHS compliant
- Solder hot dip Tin(Sn) lead finish
- Cathode indicated by polarity band

Maximum Ratings and Electrical Characteristics

Rating at 25°C ambient temperature unless otherwise specified.

Maximum Ratings

Type Number	Symbol	Value	Units
Power Dissipation	Pd	500	mW
Maximum Forward Voltage @ IF = 100mA	V_F	1.0	V
Storage Temperature Range	T_{STG}	-65 to + 200	°C
Operating Junction Temperature	T_J	+ 200	°C

These ratings are limiting values above which the serviceability of the diode may be impaired.

ELECTRICAL CHARACTERISTICS (TA=25°C unless otherwise noted)

Device Type	V_Z at I_{ZT} (Volts)		I_{ZT}	Z_{ZT} @ I_{ZT} Ohms	I_{ZK}	Z_{ZK} @ I_{ZK} Ohms	I_R @ V_R uA	V_R
	Min	Max	mA	Max	mA	Max	Max	V
BZX55C2V0	1.88	2.11	5.0	100	1.0	600	100	1.0
BZX55C2V2	2.08	2.33	5.0	100	1.0	600	100	1.0
BZX55C2V4	2.28	2.56	5.0	85	1.0	600	50	1.0
BZX55C2V7	2.51	2.89	5.0	85	1.0	600	10	1.0
BZX55C3V0	2.8	3.2	5.0	85	1.0	600	4.0	1.0
BZX55C3V3	3.1	3.5	5.0	85	1.0	600	2.0	1.0
BZX55C3V6	3.4	3.8	5.0	85	1.0	600	2.0	1.0
BZX55C3V9	3.7	4.1	5.0	85	1.0	600	2.0	1.0
BZX55C4V3	4.0	4.6	5.0	75	1.0	600	1.0	1.0
BZX55C4V7	4.4	5.0	5.0	60	1.0	600	0.5	1.0
BZX55C5V1	4.8	5.4	5.0	35	1.0	550	0.1	1.0
BXZ55C5V6	5.2	6.0	5.0	25	1.0	450	0.1	1.0
BZX55C6V2	5.8	6.6	5.0	10	1.0	200	0.1	2.0
BZX55C6V8	6.4	7.2	5.0	8	1.0	150	0.1	3.0
BZX55C7V5	7.0	7.9	5.0	7	1.0	50	0.1	5.0
BZX55C8V2	7.7	8.7	5.0	7	1.0	50	0.1	6.2
BZX55C9V1	8.5	9.6	5.0	10	1.0	50	0.1	6.8
BZX55C10	9.4	10.6	5.0	15	1.0	70	0.1	7.5
BZX55C11	10.4	11.6	5.0	20	1.0	70	0.1	8.2
BZX55C12	11.4	12.7	5.0	20	1.0	90	0.1	9.1
BZX55C13	12.4	14.1	5.0	26	1.0	110	0.1	10
BZX55C15	13.8	15.6	5.0	30	1.0	110	0.1	11
BZX55C16	15.3	17.1	5.0	40	1.0	170	0.1	12
BZX55C18	16.8	19.1	5.0	50	1.0	170	0.1	14
BZX55C20	18.8	21.2	5.0	55	1.0	220	0.1	15
BZX55C22	20.8	23.3	5.0	55	1.0	220	0.1	17
BZX55C24	22.8	25.6	5.0	80	1.0	220	0.1	18
BZX55C27	25.1	28.9	5.0	80	1.0	220	0.1	20
BZX55C30	28	32	5.0	80	1.0	220	0.1	22
BZX55C33	31	35	5.0	80	1.0	220	0.1	24
BZX55C36	34	38	5.0	80	1.0	220	0.1	27
BZX55C39	37	41	2.5	90	0.5	500	0.1	28
BZX55C43	40	46	2.5	90	0.5	600	0.1	32
BZX55C47	44	50	2.5	110	0.5	700	0.1	35
BZX55C51	48	54	2.5	125	0.5	700	0.1	38
BZX55C56	52	60	2.5	135	0.5	1000	0.1	42
BZX55C62	58	66	2.5	150	0.5	1000	0.1	47
BZX55C68	64	72	2.5	160	0.5	1000	0.1	51
BZX55C75	70	80	2.5	170	0.5	1000	0.1	56

Notes:
1. Tolerance and voltage designation: the type numbers listed have zener voltage as shown.
2. Specials available include: nominal zener voltages between the voltages shown and tighter voltage, for detailed information on price, availability and delivery.
3. Zener voltage (V_Z) measurement: the zener voltage is measured under pulse conditions such that T_J is more than 2°C above T_A.
4. Zener impedance (Z_Z) derivation: zener impedance is derived from the 60-cycle ac voltage, which results when an ac current having an RMS value equal to 10% of the dc zener current (I_{ZT}) is superimposed to IZT.